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The Course of Oil

By K. C. SCLATER

Apprehension Over Court Decision

During 1939 Texas produced 460 million barrels of oil, or 38 percent of the nation's total. This huge volume represents but a fraction of the potential production of 88,000 wells.

Of Texas' 254 counties, 147 are productive of oil. Exploration was carried on in 98 others, leaving only nine counties that did not produce oil or were not actively explored for oil during 1939.

Impressive as these figures are, the magnitude of refining operations in Texas is equally striking. The expansion in refining operations even outstrips that of oil production. In 1933, little more than 50 percent of the oil produced in Texas was refined within its borders. Today, 153 refineries refine 80 percent of the oil produced. Refinery workers number 25,000 and represent an annual pay roll of 40 million dollars.

With this magnificent stake in oil, it is no wonder that Texas was apprehensive over the recent adverse court decision on proration regulations in the East Texas field. These were held invalid by a three-judge Federal court. The decision is a critical one, so critical that the Texas Railroad Commission has appealed the case. Should the decision be upheld, it may mean writing for the East Texas field a new proration order the ultimate effect of which may be far-reaching.

In order not to precipitate a crisis, the Court suspended judgment pending an appeal by the Railroad Commission. A settlement of this case may be forthcoming within sixty days. When it does, it may herald another era in proration, not only for the East Texas field, but for every field in the state. Whatever the outcome, it is hoped that the oil industry of Texas will not suffer thereby or have any cause to resort to drastic action, and that the question of proration in the East Texas field will be settled once and for all.

Cole Bill Hearings Concluded

Among the last witnesses to testify before the Cole Committee in Washington during the latter part of February were engineers, operators, and state officials. Solid opposition to federal control was expressed on the grounds that federal control could accomplish nothing that is not now being done toward the elimination of avoidable waste.

What action the committee will take in reporting the bill is not known. According to reports from Washington, it is understood that the committee is opposed to the bill in its present form. The bill may be rewritten, so as to provide for federal control only in oil-producing states that do not have conservation laws. This would include California and Illinois.

About a year ago, California adopted a voluntary curtailment plan. This plan has found favorable and wide acceptance among all classes of producers, large and small. It does not work any hardship or abuse on any individual or group of individuals or company, and it has proved to be more equitable than any plan yet tried. The adoption and success of this curtailment plan, and also the fact that it is voluntary, certainly do not lend support to the need for federal control in California.

As for Illinois, waste in that state is not so bad as is generally believed. So much has been said about unrestricted production and waste that the two have become synonymous when Illinois is mentioned. Despite what proponents of the Cole bill would have us believe, production without proration does not necessarily mean waste. Either by accident or design, the facts regarding waste in Illinois have been greatly distorted.

Not much is heard about the advanced practices in use. In several of the larger and more prolific fields in Illinois the most modern methods of production are being applied to conserve energy, increase ultimate recovery, and reduce waste. These methods include large-scale gas injection early in the life of the pool by returning residue gas to the formation under high pressure.

Illinois will work out its own problem of conservation as soon as its citizens and lawmakers really awake to the folly of producing at high uneconomic rates of flow.

Threat Demands Action

Threat of federal control from another source is seen in recent contentions of attorneys of the Federal Power Commission regarding its authority in regulating the Natural Gas Industry. Such regulation concerns natural gas only as a public utility and has nothing to do with conservation or waste.

The threat arises from the fact that attorneys for the Federal Power Commission would interpret certain sections of the Natural Gas Act in such a way that it may involve all wells that produce oil with gas. The section of the Natural Gas Act referred to says that its provisions "shall apply to the transportation of natural gas in interstate commerce, to the sale in interstate commerce of natural gas for resale for ultimate public consumption . . . but shall not apply to any other transportation or sale of natural gas or to the local distribution of natural gas or to the facilities used for such distribution or to the production or gathering of natural gas." Although the purpose of the law in the statement that it "shall not apply . . . to the production or gathering of natural gas" seems clear, Federal Power Commission attorneys in a brief now before the Commission contend that *this negative language does not impair the force of the affirmative language in the section.* As nearly all wells produce gas with the oil and this gas supplies the energy for lifting the oil, it may be considered as an incidental by-product of petroleum production. Certainly "if the production of this incidental by-product is regulated through restrictions of its sale under the pretense that it is a public utility, then the production of the primary material—the petroleum—is equally affected."

Regulation of this sort is an even more drastic form of government control than that contained in the Cole Bill. The Federal Power Commission should be apprised before it is too late.

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« « HIGHLIGHTS IN OILDOM » »

Hold Pipe Lines Not Operated As Common Carriers

The Interstate Commerce Commis- has received a report from Examiner J. Paul Kelly that the investigation into the lawfulness of reduced rates and gathering charges for the interstate transportation of crude petroleum by pipe line, in which 37 pipe-line carriers were made respondents, be discontinued because the rates, rules, regulations, and practices of the companies are not shown to be unlawful as they affect interstate commerce.

The proposed report states that the pipe lines are being operated as plant facilities of the large oil refineries, and are not being operated as common carriers. On this point it says in part:

"Although under the law they are common carriers, they are not being operated as common carriers in fact. The oil companies own the pipe lines and several of the larger companies have dissolved the separate corporate entities under which their pipe lines were formerly operated and these pipe lines are now being operated as departments of the respective oil companies named."

The following additional excerpts from the report are pertinent:

"Summarizing the facts of record and speaking generally, it appears that because of established practice in the oil industry, the market for crude petroleum is at the well. The operations of respondents, functioning as plant facilities of the oil companies, is to bring that crude petroleum at the direction of the owners to the respective refineries of the oil companies. Because the law declares that all pipe lines are common carriers, the respondents publish rates and file their tariffs with the Commission and because it suited the convenience of the oil companies in the past, the rates of the pipe lines were high and the profits derived from transportation in the form of dividends paid by the pipe line companies were enormous. Increased volume of production and revision of corporation tax laws have made it desirable for the latter companies to derive less profit from transportation. Rates therefore have been reduced and the evidence indicates that the reductions are to continue in the future because in the face of increased production, the reduction in rates has not been sufficient to greatly reduce the net earnings of most of the respondents, that is, those affiliated directly with large oil companies. * * *"

●

U. S. Supreme Court to Review Proration Decision

The United States Supreme Court has agreed to review the decision of the Fifth Circuit Court of Appeals involving oil proration orders of the Texas Railroad Commission, which sustained a district court decision that certain orders issued by that body were arbitrary, unreasonable, and confiscatory. The case in point is that brought by Rowan and Nichols Oil Company, which sought an injunction against orders of the commission limiting the amount of oil that could be produced from the company's Todd E lease in the East Texas field.

Rowan and Nichols Oil Company brought the suit in district court against the commission's orders on the grounds that the order did not allocate total production allowed for the field among the various wells ratably on a basis proportionate to the total potential production of each well. An injunction was granted and the commission appealed, contending that the court had erred in several respects, principally in its findings that the commission must establish proration in such a manner as to allocate to the Rowan and Nichols wells a daily allowable production that bears to the total daily allowable for the field the same ratio that the estimated recoverable oil beneath such leases bears to the estimated recoverable oil in the entire field, to the exclusion of all other relevant physical and engineering factors.

Attorney General Mann, in making his petition to the United States Supreme Court, argued that the method of proration outlined by the lower courts is "confiscatory" in two ways: "First, by eliminating the twenty-barrel allowable, it would so reduce the allowable of wells on small tracts as to make it impossible for the owners of such tracts to produce oil from beneath such tracts; and, second, it would confiscate the property of the owners of leases in the western part of the field by accelerating the natural eastward migration of the oil and making it impossible for such owners to produce more than a fraction of the oil beneath their leases."

●

Ask High Court To Review Elk Hills Decision

Attorney General Earl Warren of California, joined by Attorney General Filo M. Sedillo of New Mexico, has filed a petition with the United States Supreme Court asking that body to reconsider its refusal to review the decision of a circuit court that awarded to the Federal Government title to land in the Elk Hills oil field, California. It was pointed out in the brief that income from the land is used for the support of the California school system and that the decision will also affect other states.

The petition said: "May we respectfully urge that the court consider the interest of some of the newer states whose public school systems depend upon the sale of school lands as a major source of school income. These lands can only be sold if, in the opinion of the legal profession advising title companies, the title to them is marketable."

●

Bill to Control Kentucky Production Is Tabled

A bill introduced in the Kentucky Legislature to provide for an oil and gas commission to regulate production has been tabled. As the next session of the state legislature is not until 1942, production will go unregulated for at least two more years.

●

Sweden to Produce Oil From Shale on Large Scale

The Swedish Riksdag recently appropriated 5,500,000 crowns to increase the production capacity of the shale oil works at Kinnekulle. These works, which are controlled by the Royal Navy, have until now been operated in a small way on an experimental basis.

The Royal Geographical Survey Bureau has estimated that there are about 500 million tons of shale containing 4 percent or more oil in the Province of Ostergötland, about 150 million tons in the province of Närke, and 50 million tons at Kinnekulle. There are also deposits of 300 million tons of shale containing slightly less oil on the Island of Oland and 1000 million tons in the highlands south of Kinnekulle. The richer oil shale deposits in the Provinces of Ostergötland, Närke, and Västergötland alone, it is estimated, would yield approximately 300 million tons of crude oil from which could be extracted 150 million tons of Diesel oil. In addition, 120 million tons of gasoline and several million tons of lubricating oil of a fairly good quality could be derived.

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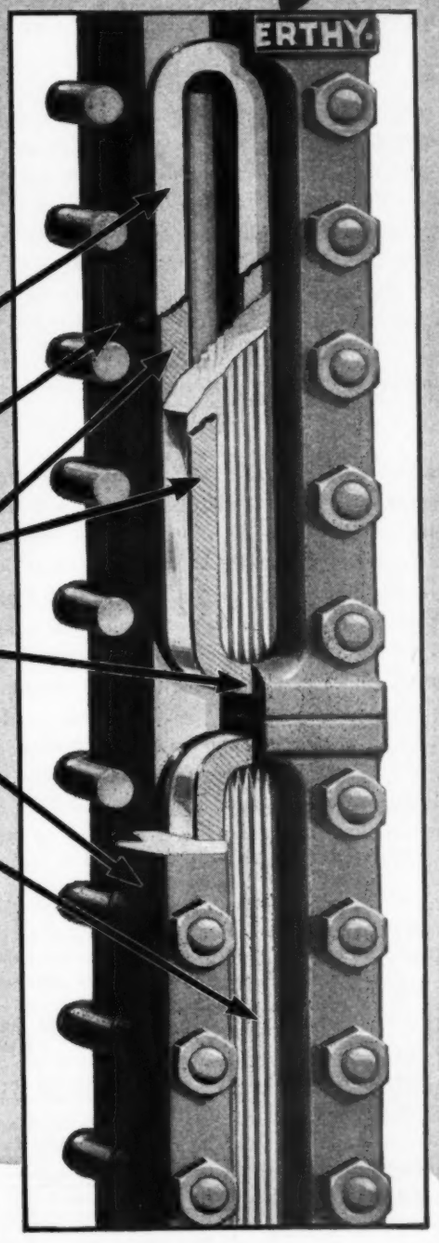

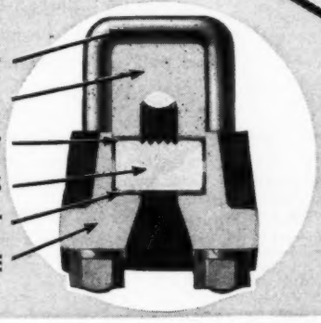

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Activities in Refining

Percent Refining Capacity Operated

Western Division, 59.9 Percent **Central Division, 76.9 Percent** **Eastern Division, 89.6 Percent**

A REFORMING and thermal-polymerization unit will be installed in the Magnolia Petroleum Company's Beaumont, Texas, refinery. The announcement was made in Beaumont recently by John A. Brown of New York City, president of Socony-Vacuum Oil Company, of which Magnolia is a subsidiary. Meeting Brown in Beaumont to inspect the facilities of the Socony-Vacuum subsidiary were D. A. Little, Dallas, Texas, president of Magnolia Petroleum Company, and A. L. Weil, Los Angeles, California, president of General Petroleum Corporation of California, also a subsidiary.

●

Continental Oil Company has announced improvements to its refinery at Wichita Falls, Texas, that will involve an expenditure of approximately $700,000. The principal addition will be a thermal-polymerization unit that will have a capacity for producing 500 bbl. per day of high octane polymer gasoline from 2500 bbl. of casinghead gasoline and 1650 bbl. of refinery stock. This product will be blended with other gasolines to make a high-quality motor fuel.

The thermal-polymerization unit will consist of a large furnace used as a cracking coil and three smaller furnaces that will be used as preheaters and reboilers, five towers, a 500-hp. engine to drive the charge pump, and an induced-draft water-cooling tower having a capacity of 3000 gal. per min.

●

Hunt Oil Company, Dallas, Texas, has begun the erection of a recycling plant in the Long Lake field, Anderson County, Texas, on the H. B. Keeling tract near Tucker. It will be the fourth such unit in the field.

The company has unitized gas-distillate holdings in the vicinity of the Keeling acreage and will serve several wells already completed and others to be drilled.

The last recycling plant to be completed in the Long Lake field is that of the Tide Water-Associated Oil Company. Byrd-Frost, Inc., and Trinity Gas Corporation also have plants in the area.

Canadian Oil Companies, Ltd., Petrolia, Ontario, Canada, will remodel its present topping and cracking unit in line with the latest Dubbs operating methods, it has been announced.

As revamped, the existing cracking unit will crack about 1300 bbl. per day of topped crude oil. The plant will run about 2800 bbl. a day of Illinois crude oil.

Equipment will also be added to reform 500 bbl. of straight-run gasoline and naphtha per day.

A Universal Oil Products Company catalytic polymerization unit, to produce polymer gasoline from the cracked gases, will be a feature of the refinery.

In remodeling the cracking unit, provision will be made for future conversion to 2-coil operation, having a cracking capacity of 2000 bbl. per day.

John Irwin is president of Canadian Oil Companies, Ltd., Frank C. West is vice-president, Earl A. Smith is refinery superintendent, and V. Norwood, refinery technologist.

●

North Star Oils, Ltd., St. Boniface, Manitoba, Canada, will install a 500-bbl. per day single-coil Dubbs cracking unit, it has been announced by officials of the company.

Specifications and design will be supplied by the Born Engineering Company, Tulsa, Oklahoma.

Provision will be made in the design for conversion of the unit to 2-coil operation at a later date.

The company now has a skimming plant running 1200 bbl. of Turner Valley crude oil per day.

Colonel George Chisholm is president of the company and T. M. Clayton, vice-president and general manager.

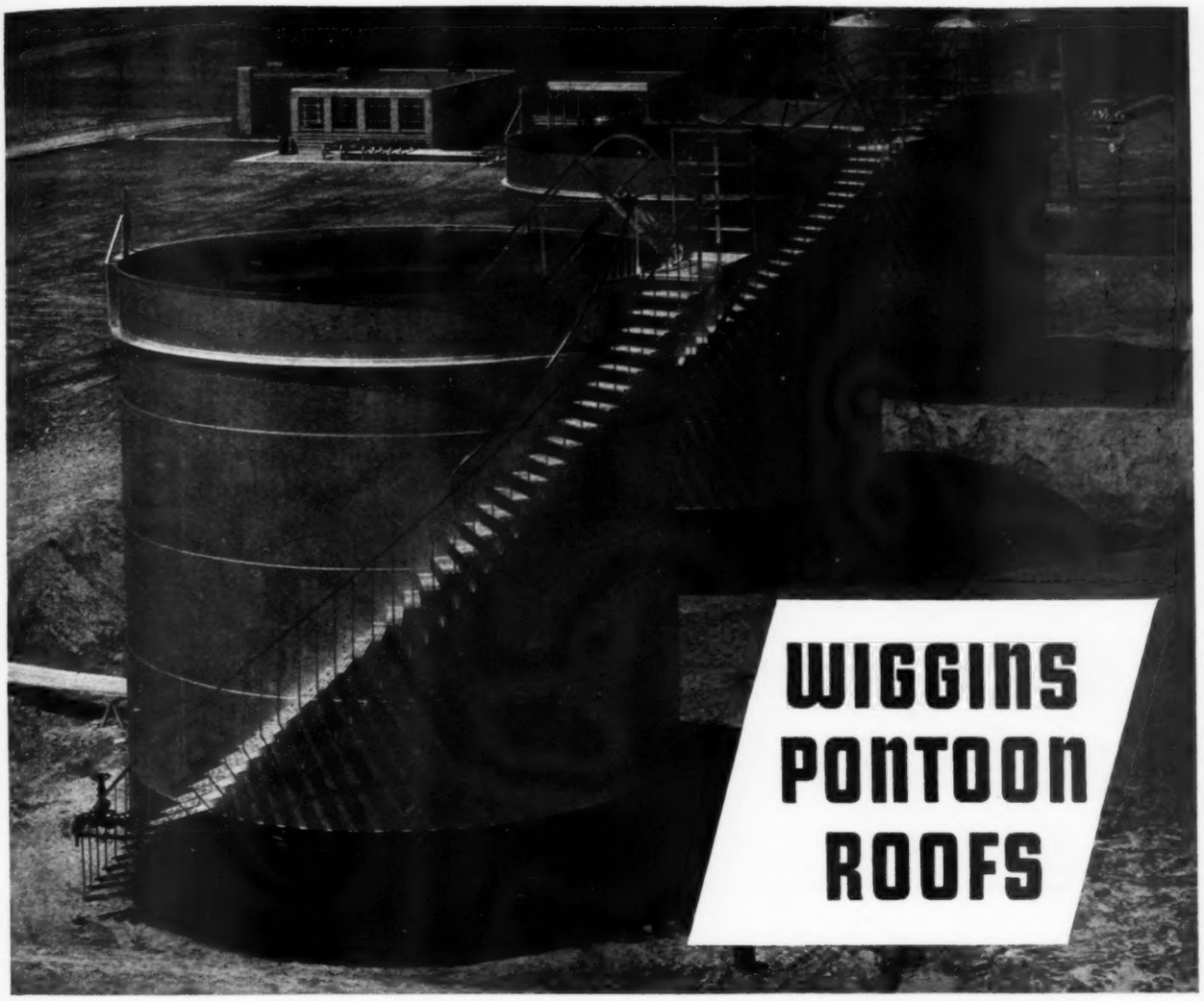
●

W. R. Davis, Inc., has awarded a contract to Hudson Engineering Company, Houston, Texas, for the installation of a recycling plant in the East Alice field, Jim Wells County, Texas. The capacity of the plant will be 60,000,000 cu. ft. of gas per day. Gas will be returned to producing zones at depths of 4700 ft. and 5100 ft.

Crude Runs to Stills, Gasoline, Gas and Fuel Oil Stocks
Week Ended March 2, 1940
A.P.I. Figures
(Figures in thousands of bbl. of 42 gal. each)

DISTRICT	Percent Potential Capacity Reporting	Daily Average Crude Runs to Stills	Percent Operated of Total Capacity Reporting	Total Motor Fuel Stocks	Total Gas and Fuel Oil Stocks
East Coast	100.0	540	87.8	19,624	14,322
Appalachian	87.3	125	86.2	3,924	1,048
Ind., Ill., Ky.	90.7	555	94.9	16,723	5,401
Okla., Kans., Mo.	81.6	272	79.5	8,807	3,065
Inland Texas	50.3	117	73.6	2,132	1,771
Texas Gulf	90.0	822	86.5	16,575	8,914
La. Gulf	97.8	120	68.6	3,159	1,756
No. La. and Ark.	55.0	42	76.4	756	691
Rocky Mt.	54.2	38	59.4	1,702	653
California	90.0	451	60.5	18,122	88,230
Reported	86.4	3,082	80.4	91,524	125,851
Estimated Unreported	.....	363	.....	6,840	2,685
*EST'D TOTAL U. S. Mar. 2, '40	.....	3,445	.....	98,364	128,536
*EST'D TOTAL U. S. Feb. 24, '40	.....	3,490	.....	96,719	128,809
U. S. B. of M. *March 2, 1939	.....	**3,074	.....	85,506	140,948

*Estimated U. S. Bureau of Mines' basis.
**February-March, 1939, daily average.



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The seal on a pontoon roof consists of a long, single shoe (for tanks with butt welded shells) or a series of steel shoes joined together in a ring which forms a long, sliding contact with the tank shell. A band of flexible material is used to close the space between the top of the shoes and the pontoon deck.

To enable the shoes to pass over the joints or other irregularities in lap welded or riveted tank shells, the tops and bottoms of the shoes are curved away from the shell. In addition, the shoes on such tanks are equipped with secondary seals, to prevent air currents from penetrating the space between the shoe and the tank shell when shoe passes over joints.

Wiggins Pontoon Roofs are used extensively on working tanks at pipe line stations. An example is illustrated above, where three pontoon roof tanks are installed at the Lima, Ohio, station of the Shell gasoline pipe line. Two of these units have a capacity of 3000-bbls., the third 5000-bbls. Our nearest office will be glad to furnish information or quotations on Wiggins Pontoon Roofs for your tanks.

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Activities in the Oil Fields

MABEE Oil and Gas Company's No. 24 Willard, between the Bennett and Denver areas of the Wasson pool, Yoakum County, West Texas, flowed 1363 bbl. per day from a depth of 5185 ft. after an 8500 gal. acid treatment.

●

McMahon No. 1, a wildcat in SW SE of 31-17-1e, Logan County, Oklahoma, produced 4 bbl. of oil per hr. and from 10,000,000 to 15,000,000 cu. ft. of gas after a 1000-gal. acid treatment through perforations above the second Wilcox sand. The well, east of the South Langston pool, was drilled by Helmerich and Payne, Inc., and Wilcox Oil and Gas Company. Production is from Viola Lime and Simpson Dolomite, no water being evident.

●

A wildcat two miles west of the city limits of Wichita, Kansas, the No. 1 Charles Stilt, CSL SE NE 21-27-1w, drilled by G. A. Fuller and Charles Starck, has a commercial showing of oil, estimated at 75 bbl. per day, from the Kansas City lime, at a depth of 2795 ft.

●

Searching for gas within the city limits of Amarillo, Texas, a test well being drilled by Canadian River Gas Company, No. 1 City of Amarillo, produced light gravity oil in a bailer test from a depth of 3797 ft. The producing horizon is reported as an unidentified dense white dolomite limestone.

●

A new pool three miles southwest of Ringgold, Montague County, Texas, was assured when the well drilled by W. Bland Omohundro on the Wilmer Seay farm began flowing at a depth of 5696 ft. Omohundro, pioneer North Texas wildcatter, who has drilled 39 dry holes in succession, had once considered abandoning the test at a depth of 5000 ft.

Second largest well in Illinois, The Texas Company's No. 24 McCollum, in the Lake Centralia-Salem field, flowed 1553 bbl. in a 3-hr. test from the Devonian lime at a depth of 3409 ft. This rate establishes a daily potential of 12,424 bbl.

●

A new pool one mile from the town of Lancaster, Wabash County, Illinois, was opened by No. 1 Seibert of Hank Riddle et al, flowing 365 bbl. of oil in 22 hr., in heads through casing from the McClosky lime at a total depth of 2743 ft.

●

Skelly Oil Company's No. 105 Schafer Ranch, in section 172, block 3, I & G N Survey, Gaines County, Texas, was completed at 3328 ft. for a potential of 1206 bbl. per day.

●

Tinsley Dome field, Yazoo County, Mississippi, now has 25 producing wells following completion of Edgar Johnson's No. 2 Brumfield, in SW SE 2-10n-3w. The well flowed 54 bbl. per hour from a depth of 4782 ft.

●

Plymouth Oil Company's No. 1 McHugh heirs, a wildcat in 13-12s-10e on a Shell Oil Company farmout in the Bayou Pigeon area, Iberia Parish, Louisiana, flowed pipe line oil in drill stem tests from depths of 7944-50 ft. and 8047-71 ft.

●

A new oil pool in Illinois may result from the drilling of Pure Oil Company's No. 1 Warren in 33-6n-10e near Newton, Jasper County. On a drill stem test, the well showed 270 ft. of oil and 240 ft. of gas-cut mud from the McClosky lime at 2487 ft. Potential of the well is estimated at 200 to 400 bbl. per day.

AVERAGE CRUDE OIL PRICES

California	
Kettleman Hills	$1.12-1.38
Playa Del Rey	.65-1.08
Coalinga	.60- .82
Wilmington	.64-1.14
Montana	.90-1.10
Wyoming	.35-1.80
Colorado	.90- .98
New Mexico	.53- .95
Texas	
North Central	.71-1.03
Panhandle	.67- .96
West Texas	.53- .95
Gulf Coast	.86-1.28
Darst Creek	.96
East Texas	1.10
Talco	.65
Kansas	.60-1.10
Oklahoma	.60-1.10
Arkansas	.73-1.05
Louisiana	
Rodessa	$1.05
Gulf Coast	.79-1.28
North Louisiana	.73-1.05
Illinois	.95-1.05
Kentucky	.90-1.10
Indiana	.95
Ohio	
Lima	.90
Michigan	.74-.97½
Pennsylvania	
Bradford	2.75
Southwest	2.40
Eureka	2.34
Buckeye	2.30
Corning	1.12
Canada	2.10-2.17

Daily Average Crude Oil Production
Data Supplied by A.P.I.

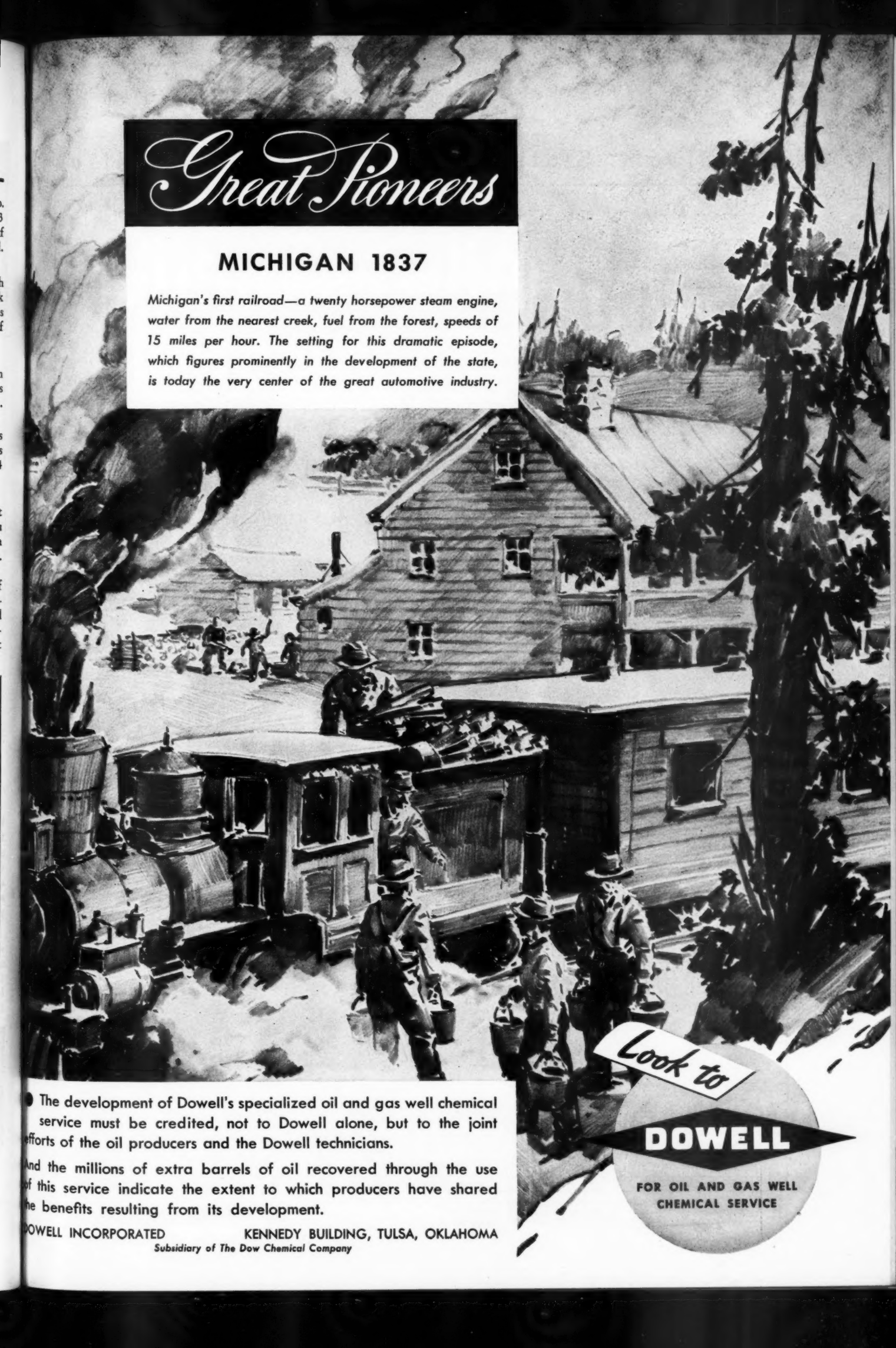
(Figures in bbl. of 42 gal. each)

	[1]B. of M. Calculated Requirements (February)	Week Ended March 2, 1940	Week Ended February 3, 1940	Week Ended March 4, 1939
Oklahoma	429,000	[2]407,550	[3]405,650	441,200
Kansas	155,500	[2]176,900	[3]181,600	144,900
Nebraska	.....	.....	[3] 100	.....
Panhandle Texas	.....	78,400	70,000	68,650
North Texas	.....	104,650	84,000	80,800
West Central Texas	.....	33,100	33,000	30,600
West Texas	.....	251,600	195,850	208,800
East Central Texas	.....	79,600	66,950	96,700
East Texas	.....	484,000	394,600	372,650
Southwest Texas	.....	227,950	193,600	246,600
Coastal Texas	.....	237,650	294,300	216,250
TOTAL TEXAS	1,371,400	1,496,950	1,242,300	1,321,050
North Louisiana	.....	69,150	68,350	72,100
Coastal Louisiana	.....	211,900	203,250	194,550
TOTAL LA.	252,800	281,050	271,600	266,650
Arkansas	60,000	69,000	70,650	52,700
Mississippi	700	[2] 6,800	[3] 4,600	.....
Illinois	325,500	402,600	372,950	158,050
Indiana	5,200	[2] 9,650	[3] 6,600	
Eastern (Not incl. Ill.) and Ind.)	103,700	100,450	94,850	96,400
Michigan	64,500	63,850	63,250	56,000
Wyoming	55,200	65,200	61,550	48,650
Montana	15,200	17,200	17,050	14,250
Colorado	4,100	3,950	4,800	3,800
New Mexico	100,300	112,500	101,050	101,900
TOTAL EAST OF CALIF.	2,943,100	3,213,650	2,898,600	2,705,550
California	585,900	584,600	600,200	609,300
TOTAL U. S.	3,529,000	3,798,250	3,498,800	3,314,850

[1]These are U. S. Bureau of Mines' calculations of the requirements of domestic crude oil based upon certain premises outlined in its detailed forecast for the month of February. As requirements may be supplied either from stocks, or from new production, contemplated withdrawals from crude oil inventories must be deducted from the Bureau's estimated requirements to determine the amount of new crude to be produced.

[2]Oklahoma, Kansas, Nebraska, Mississippi, and Indiana figures are for week ended 7:00 A. M., February 28.

[3]Oklahoma, Kansas, Mississippi, and Nebraska figures are for week ended 7:00 A. M. December 27.


Great Pioneers
MICHIGAN 1837
Michigan's first railroad—a twenty horsepower steam engine, water from the nearest creek, fuel from the forest, speeds of 15 miles per hour. The setting for this dramatic episode, which figures prominently in the development of the state, is today the very center of the great automotive industry.
Look to
DOWELL
FOR OIL AND GAS WELL CHEMICAL SERVICE

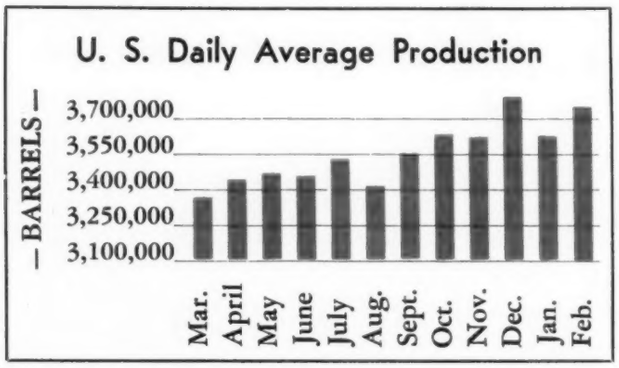
The development of Dowell's specialized oil and gas well chemical service must be credited, not to Dowell alone, but to the joint efforts of the oil producers and the Dowell technicians.

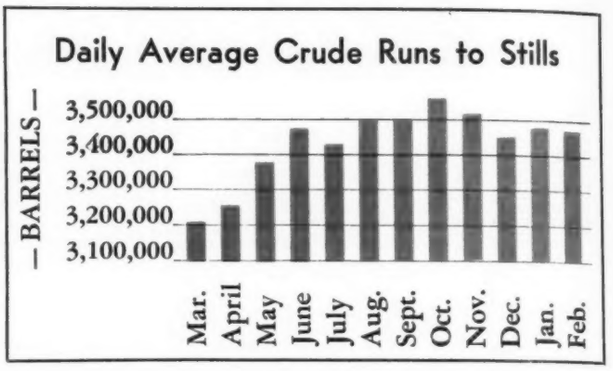
And the millions of extra barrels of oil recovered through the use of this service indicate the extent to which producers have shared the benefits resulting from its development.

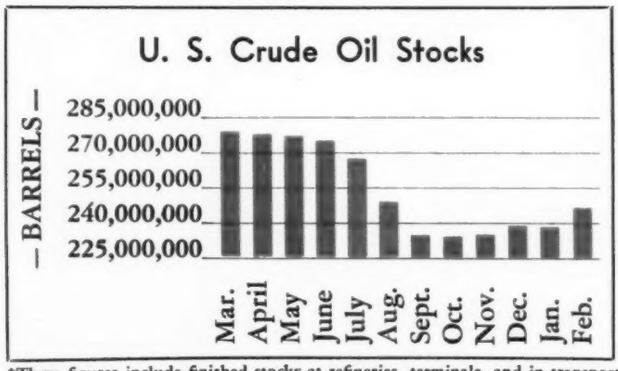
DOWELL INCORPORATED KENNEDY BUILDING, TULSA, OKLAHOMA

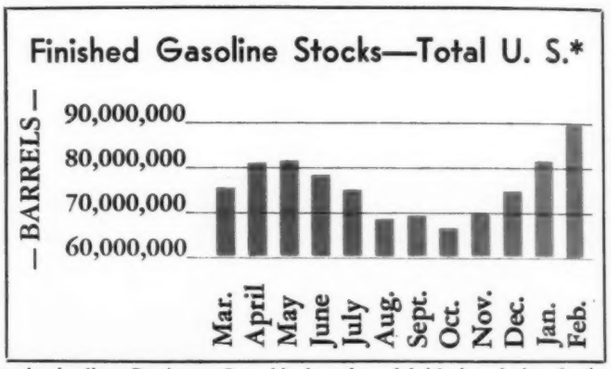
Subsidiary of The Dow Chemical Company

Petroleum Statistics and Field Activities









*These figures include finished stocks at refineries, terminals, and in transportation in pipe lines. Previous to June this chart showed finished stocks in refineries only. Above statistics by the American Petroleum Institute.

Summarized Operations in Active Fields for February, 1940

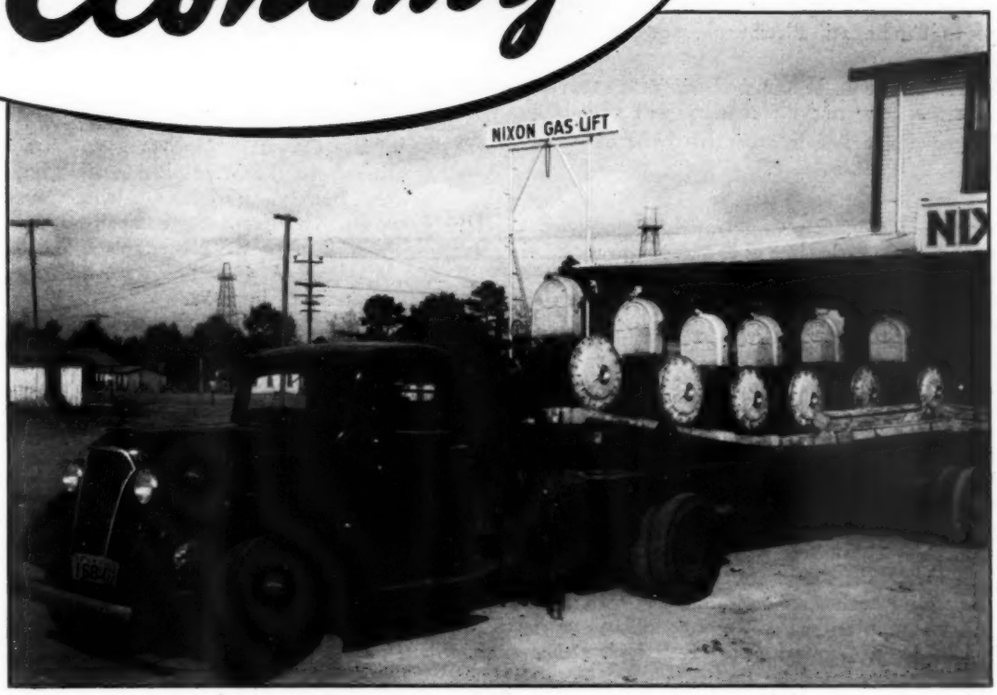
Fields	Completions	Producers	Rigs	Drilling Wells	Depth of Production	No. Casing Strings	Gravity of Oil	Type of Tool Used
Texas								
East Texas	31	31	3	17	3500-3700	2	40	Rotary
Duval County	31	18	3	10	1554-2900	2	22	Rotary
Ector County	56	54	10	63	3675-4377	2 and 3	32-36	Rot.-Cab.
Panhandle	39	36	13	52	1700-3900	2	40	Rotary
Refugio County	10	10	2	5	4900-5900	2	38	Rotary
Nueces County	8	6	2	9	3922-5878	2 or 3	21-54	Rotary
K. M. A. Field	29	29	20	36	3730-3935	2	42-43	Rot.-Cab.
Oklahoma								
Fitts Pool	16	12	2	6	1800-4488	2 or 3	38	Rotary
Kansas								
Russell County	21	19	9	25	2926-3435	2 and 5	32-37	Rot.-Cab.
Rice County	16	15	6	22	3222-4085	2 and 5	42-48	Rot.-Cab.
Barton County	12	8	4	21	3290-3518	2	39-42	Rot.-Cab.
Illinois								
Central Illinois	288	251	330	134	1425-4100	2	36-38	Rot.-Cab.
New Mexico								
Lea County	38	37	10	47	3150-4030	3	30-34	Rot.-Cab.
California								
Kettleman Hills	3	3	3	14	8300-8730	3 or 4	40	Rotary
Wilmington	16	16	10	12	3500-4000	2 and 3	18-20	Rotary

Field Activities by States for February, 1940

State	Completions		Producers		Locations		Rigs		Drilling Wells		Production, 1939 (In Barrels)
	February	January	February	January	February	January	February	January	February	January	
Arkansas	14	14	10	12	9	8	3	4	35	39	21,266,994
California	89	118	83	104	87	117	70	105	181	190	224,336,682
Colorado	....	2	....	1	....	....	1	1	20	25	1,402,599
Illinois	288	234	251	184	310	446	330**	321†	134	86	92,915,620
Indiana	25	32	12	21	....	....	6	5	68	71	1,426,000
Kansas	105	121	88	101	143	140	45	46	270	275	59,952,340
Kentucky	12	22	8	12	....	....	8	11	81	91	5,611,500
Louisiana	120	123	100	100	128	122	39	32	185	187	94,110,736
Michigan	103	112	66	76	68	160	60	50	175	181	23,185,203
Mississippi	12	14	7	9	....	....	4	3	20	23	102,918
Montana	5	19	4	14	....	....	5	3	38	40	5,901,058
New Mexico	62	74	54	59	46	81	20	26	135	146	37,453,117
New York	81*	94*	75*	94*	....	....	20	15	61	44	5,105,000
Ohio	50*	105*	39*	78*	....	....	55	45	171	182	3,157,500
Oklahoma	159	153	107	91	129	189	52	56	299	323	156,421,939
Pennsylvania	204*	193*	186*	173*	....	....	....	....	....	....	17,342,500
Tennessee	0	0	0	0	....	....	....	....	....	....	....
Texas	840	830	636	643	871	1148	490	493	1590	1598	485,847,999
West Virginia	45	72	44	57	....	....	22	20	137	142	3,556,500
Wyoming	9	20	8	17	....	....	7	3	54	60	21,408,478
Total	2223	2352	1778	1846	1791	2411	1237	1239	3654	3703	1,260,504,683

*Includes water-intake and pressure wells.
**Includes 257 rigs standing and 73 rigging-up.
†Includes 253 rigs standing and 68 rigging-up.

Proration forces *Economy*



Prorated production, being the order of the day, forces every oil operator to look for the most economical means of producing his wells.

And above is pictured how one of many operators start economizing, by hauling six Nixon Gas-Lift units on a light truck. These units will be installed on six wells that have ceased flowing and now require artificial means of fluid lifting.

This economy of transportation is only the beginning. Lower installation cost, combined with operating economies, which continue until the well is completed, make it far cheaper to lift fluid with the Nixon Surface Control Gas-Lift System. Ask a Nixon Gas-Lift engineer to show you how to reduce your production cost. Write your nearest Wilson Supply Company store or sales office.

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EXCLUSIVE GULF COAST DISTRIBUTORS FOR: Wilson-Snyder Pumps; American Cable Tru-Lay Pre-formed Wire Rope; Kewanee Boilers; Sievers Reamers; Drift Meter, Jr.; Gray Swivel; Nixon Surface Control Gas Lift; Nixon True-Taper Slip and Spider; Bowen Pack-off and Releasing Drill Pipe Overshot; Douglas Weight Indicator; Coffey Robot Stack Draft.

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TEXAS: Gladewater; Barbers Hill; Bay City; Monahans; Alice; Victoria; Corpus Christi.
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Major Pipe Line Activities

THE LAWRENCE Pipe Line Company has been organized as a subsidiary of The Texas Corporation to lay a 6-in. gasoline pipe line from Lawrenceville, Illinois, to Evansville, Indiana, a distance of 53 miles.

The parent company has a refinery with a capacity of 22,000 bbl. per day at Lawrenceville; products from this refinery will be pumped through the line to Evansville, which is on the Ohio River, from where they will be shipped by barge to Cincinnati, Pittsburgh, and St. Louis for distribution.

A terminal will be constructed at Evansville and it is possible the Lawrenceville refinery will be enlarged.

The new pipe line is expected to be in use sometime in June.

●

Southern Union Gas Company has completed the laying of 31 miles of 5½-in. line as extensions to its existing system to serve the towns of Belen, Los Lunas, and Isleta, New Mexico. Fredell Construction Company was the general contractor and Pipe Line Service Corporation coated the line.

●

Continental Oil Company is rebuilding the pipe line system recently purchased from the Crude Oil Pipe Line Company. The system is in the South Texas area and includes a marine terminal at Corpus Christi.

Between San Diego and Corpus Christi, 53 miles of 5½-in. line has been replaced by 8-in. pipe. From Banquette to the Driscoll field, 10 miles of 4½-in. line has been replaced with 5½-in. From San Diego to the Continental's property on the Driscoll Ranch a 26-mile line has been laid, and from the Alice station on the system to a point just north of the Alfred field a 6½-mile line has been laid. Other work will include 9 miles of 5½-in. line from Alice to the Magnolia City field, 7½ miles of 4-in. in the Seven Sisters field, and 7½ miles of 4-in. in the Lopez field. This work was contracted to the Latex Construction Company.

The capacity of the pump station at San Diego has been increased by the installation of a 6-cylinder, 485-hp. Diesel engine driving a 4 by 6, 6-stage centrifugal pump.

●

Continental Oil Company has announced plans for the construction of a 20-mile pipe line from the company's natural gasoline plant in the K.M.A. field, Texas, to its refinery at Wichita Falls. The capacity of the line will be 5000 bbl. per day.

●

According to recent reports the Swedish Government proposes to lay a pipe line from the west coast of Sweden to a port north of Stockholm. A storage terminal at that point will be enlarged. The pipe line will be approximately 200 miles in length and will have a capacity of 45,000 bbl. per day.

●

Louisiana-Nevada Transit Company's gas pipe line from the Cotton Valley field, Louisiana, to Okay and Hope, Arkansas, is now serving its customers at those points. At Okay the principal consumer is the Ideal Portland Cement Company and at Hope, the Hope Brick Company and the Hope Municipal Water and Light Plant.

Officers of the Louisiana-Nevada Transit Company are: T. R. Jones, Dallas, Texas, president; W. A. Delaney, Jr., Ada, Oklahoma, chairman of the board, and M. O. Matthews, Okay, vice-president.

Unconnected wells in the K.M.A. and Hull-Silk fields, Texas, are expected to be given relief by the end of the month when Sinclair Refinery Company anticipates completion of the 8-in. pipe line it is laying parallel to the 6-in. line it now operates between those areas and the Hensley station in Jack County, a distance of 66 miles.

A part of the line, that from the Predo station, in Archer County, to Hensley station, was placed in operation March 1 to help relieve the congestion. Allowables for the K.M.A. and the Hull-Silk fields are in excess of pipe-line facilities and back allowables are accumulating at a rapid rate.

●

Bay City Pipe Line Company has completed a 4-in. pipe line from the Wise Station, Isabella County, Michigan, to the Buckeye station, Gladwin County, a distance of 19 miles. This gives the company a continuous line from the Wise field to the company's affiliated refinery at Bay City, Michigan. A 6-in. line was laid from the Buckeye field to the refinery in 1938.

●

Consolidated Pipe Line Corporation has purchased the properties of the Manley Pipe Line Company, consisting of 51 miles of lines connecting the Centralia, Salem, and Sandoval fields of Illinois to Centralia refineries.

●

The Wyoming Public Service Commission has authorized the Northern Pipe Line Company to lay a 10-mile gas line from Casper to the Billy Creek field, Johnson County. The new line will take gas at Casper from the Northern Utilities Company's line and deliver it to the line of the Montana-Dakota Utilities Company at Billy Creek field. The latter company is no longer able to obtain sufficient gas from the Billy Creek field to fill its requirements. Construction of the line will begin in May.

●

Contracts have been awarded by the Magnolia Pipe Line Company for reconditioning two 27-mile sections of its 8-in. trunk line between Corsicana and Beaumont, Texas. The section between Brown station, Leon County, and Iola station, Madison County, is being reconditioned by the O. C. Whitaker Company, and the section from Richards station to the Conroe station is being reconditioned by the Mitchell Stewart Construction Company.

●

When oil was discovered by Union Producing Company in the Tinsley field, Yazoo County, Mississippi, 30 miles north of Jackson, last September, indications pointed to this section of Mississippi becoming another of the major oil-producing areas. Since discovery of the first well, others have been brought-in, and present plans of the company are to continue development of the Tinsley field with the expectation of completing a total of 40 to 50 wells by the end of the year.

As the company had no pipe lines in the area, a gathering system composed of a 6-in. main line and 2- and 4-in. lateral lines with connections to the wells has been constructed. Through this gathering system the oil is transported to United Oil Pipe Line Company's storage tanks at the tank farm on the Y & M V railroad approximately 12 miles south of Yazoo City. Here two 10,000-bbl. tanks are situated on a hill to provide gravity flow to the new 12-car double loading rack nearby.

THE Petroleum Engineer

MARCH, 1940

A PETROLEUM ENGINEER EXCLUSIVE FEATURE

Factors That Determine Profitable Secondary Recovery

By RALPH T. ZOOK, President

The Sloan and Zook Company, Bradford, Pennsylvania

This article is the substance of a paper read at Fort Worth before the National Stripper Well Association, October 17, 1939. Its value lies in the fact that the author writes from experience and describes informally and in interesting detail the procedure and the various observations and operations involved in appraising the factors that determine profitable secondary recovery. The practical nature of the discussion and information presented are such that those interested in waterflooding operations should find this article a valuable reference.—EDITOR.

SO MANY people come to me and say, "Zook, I have put water in an old well, it certainly will work on my property because it was only four days until I got a pick-up 150 ft. away." If we have a property that shows a pick-up this rapidly then we immediately begin to look for trouble. Our rate of travel in the Bradford field is only a few inches per day and it would take at least four months instead of four days to get a pick-up at this distance if conditions are favorable to water repressuring. The peak of production generally comes in from nine months to a year. This to a great extent is determined by the permeability of the sand and in Oklahoma and Kansas this peak may come at a much earlier date, but never within four or five days after water injection.

The two repressuring mediums most commonly used are water and gas, and air in some instances where the gas supply is insufficient. Using water as the first consideration, how can we determine quickly whether it may or may not be profitable? Our method of approach would be approximately as follows: Assuming a depth of 1000 ft., a sand thickness of 20 ft., and a price of oil at 90 cents per bbl.: The rough calculation would be development cost per acre of $1400.00. We know from experience this is about the right figure for it varies from this cost up to around $3000.00 per acre at 2000 ft. using orthodox well-spacing from water to water. The $1400.00 per acre is an approximate figure and is based on a spacing of 330 ft. from water to water. With 20 ft. of good solid sand our estimate of the recovery would be 4000 bbl. per acre, which after deducting the royalty of one-eighth gives the operator a net of 3500 bbl. per acre and with a development cost of $1400.00 amounts to 40 cents per bbl. We are assuming you own the property so that all you need to add to this is your operating cost and taxes, which may run in the neighborhood of 25 cents per bbl., so with a total cost of 65 cents and a price of crude at 90 cents, you have a nice margin of profit even after allowing 5 cents per barrel for interest on investment. If we had a condition like this we would then believe it would be advisable to spend the necessary money to determine if our estimate of sand thickness and recovery was sound

and the *only* way that this can be done is by coring. The core gives you much greater information than if you drilled a hole of sufficient size and it were possible for you to go down and look at the sand face. It is infinitely better than if you were able to turn the hole wrong side out and stand it up in the air so you could look at it.

Perhaps this operating cost of 20 cents or 25 cents per bbl. may seem high to you but do not fool yourself on the cost of operating water-flood properties. Our average cost in Pennsylvania in operating 1800 wells at an average depth of 1600 ft. has been over a period of 10 years 37 cents per bbl. This is exclusive of taxes and does not include overhead. One of the principal costs is that of water regardless of whether you obtain a supply of pure water from a shallow well right on the property or whether you go deep and use the siliceous lime water or whether you transport it from one of the above-ground streams at a great distance. I do not know what the ratio of water and oil will be in the Southwest, but I do know that our ratio has been 11 bbl. of water injected for every bbl. of oil produced and we have never been able to inject water under the necessary pressure at less than 1½ cents per bbl. On the discharge end we have found that we pump 9 bbl. of water for every bbl. of oil produced so that water in and water out is an expensive item. In some cases it may be of advantage for you to use sufficient pressure on your intake wells so that the oil wells will flow by hydrostatic pressure and pumping powers will not be necessary. Increased pressure, however, does mean increased water cost but under favorable circumstances, it, no doubt, will be found profitable to flow rather than to pump, at least in the earlier stages. It may be necessary to pump later in the project. If this is the case and this will only be determined by actual practice, then it may be well to install the pumping equipment first. There are sufficient flowing projects being operated at this time so that the answer on this will be available at a very early date and it may even be so at this time.

Cores

What will be the cost of this core that it seems advisable to take? In a well 1000 ft. deep we would estimate the drilling cost at 85 cents per ft. It would be necessary to use, let us say, 300 or 400 ft. of 6¼-in. casing. We have a choice of whether a diamond core or a biscuit type is to be taken. The biscuit-type barrel is a percussion type tool that operates on cable tools and is a very reasonable cost job if the barrel is available. The laboratory may have a little more difficulty with the analysis because the core will come out in small, rather thin biscuit-shaped pieces, however, we have been using this method for a number of years and have gotten along very satisfactorily. The diamond core outfit, if working properly, and it generally does, will bring out long, solid cores. This type of coring is generally and easily available throughout this part of the country. Most of the laboratories that analyze cores are in a better position to handle this type than the percussion type but I am sure that you will have no trouble in having either one of them analyzed.

After the core is taken and sent to the laboratory for analysis you will receive a report on the porosity, permeability, percent oil saturation, percent water saturation, content per acre and if it is susceptible to water-flooding, the estimated recovery per acre. If water does not seem to be the proper repressuring medium, it is possible to tell whether gas or air may be used because not all sands respond favorably to water.

What are all these things that the laboratory reports on? Porosity is the amount of space between the sand grain. Permeability is the ability to accept water. The difference is pretty well illustrated by a cup full of sugar and a cup full of peas. There may be just as much total space between the grains of sugar as there is between the peas but the peas would show less resistance to the flow of water than the sugar, or perhaps it would be better to put it in reverse and say the sugar would show a greater resistance than the peas. Perhaps even a better illustration would be sugar versus walnuts or something even larger. Percent saturation is the percentage of the pore space that is saturated with oil and percent water is the same information covering water. All the sands that I know about contain some water and, in fact, a surprisingly large amount. This water is held in the small pore spaces, it is locked there and under ordinary circumstances is not produced with the oil. It has been found, however, that it plays a rather important part in the recovery per acre and in the manner in which the property is to be operated. The content per acre is easily calculated because we know the porosity, the percent saturation and the sand thickness.

Estimating Recovery

Now what can we get from this information? The most important thing perhaps is the estimated recovery per acre. Small pieces of core are put in a flood pot in the laboratory and flooded-out under conditions somewhat similar to actual operations in the field. It is not possible to remove all the oil by water-flooding or by gas-flooding either. It has been found in Pennsylvania that if the content of the sand is reduced to 25 percent, this is as far as we can go. I believe the figure in Kansas and Oklahoma is lower than this. If we have an original content of 45 percent and we can reduce it to 25 percent, then we have a reduction of 20 percent, which is 20/45ths of the original content in that particular section of the sand, so if the content at that point is, let us say, 630 bbl./acre foot for easy figuring, we can take 4/9ths of 630, or 280, recovery for that particular foot of sand and, by the way, 630 bbl. is a pretty high oil content per acre foot, and I used it simply because it was an easy calculation to make.

Permeability also must be taken into consideration when figuring the recovery per acre. Permeability has other important factors, which we will talk about later, but we have found that there is only a certain range of permeability in which water flooding can be used. When we calculate the recovery we have to throw out the impermeable parts of the sand because the water will never travel to the oil well within any reasonable length of time and the time element alone would make it impossible to calculate this part of the pay in the recovery and when I say time, I mean time because it might take 50 years to get over to your oil well. We have found that sand with permeability ratio of 15 or 20 to 1 is within an efficient flooding range and in this case with 250 as a maximum, we would rather be inclined to believe that anything under 12 would not be recoverable unless there was some way to handle the permeable streak after it had been flooded-out; but let us say that after we have taken into consideration the factor of permeability, percent saturation of water and oil, and we have determined that the recovery per acre is sufficiently high to be attractive, if other things are favorable, then we begin to look at permeability for other indications and really this is about the most important part of what I have to say.

Variations in Permeability

Suppose a profile shows three stages of permeability, the top very soft, the middle medium, and the lower hard. You inject water or gas into a sand of this characteristic and you get an increase in production. You think that you have a nice project and maybe you have and maybe you make some money, but unless you take a core you do not know but what you are flooding only

the permeable part of the pay and getting perhaps one-third of the oil, while with a core that shows you the permeability you may be able to recover a much greater amount. In this instance, let us say, you are using water. You would flood-out the topmost permeable part and let us say your recovery per acre from it would be 2000 bbl. Unless you had the core you would think this was the best job you could do. But what would you do when you have the core data? You simply watch your oil and water production at the oil wells and after you have reached the point where your water-oil ratio is no longer profitable then you simply go into your water intake wells with a specially prepared wax distillate. Wax distillate is the product from which the lighter lubricating oils, such as neutrals, are made. I do not know whether you have a satisfactory product in this part of the country or not but right now in our part of the country (Bradford, Pennsylvania) a suitable wax distillate would cost about 12 cents per gal. in drums, say about $5.00 per drum, and three or four drums should correct the condition in any well so that the cost is not of consideration. This wax distillate is simply injected through the water intake pipe, it goes down through the open couplings and we prefer open couplings to perforated pipe, but nevertheless, perforated pipe will work also, it floats to the top of the shot hole because it is lighter than water. You calculate about the amount you think is necessary to seal off the permeable part of the sand then you reduce this about 50 percent as a matter of safety and inject this amount of wax distillate. The wax distillate goes to the top of the shot hole, the distillate part filters through the sand while the wax coats the surface of the sand and effectively seals it from any further water intake. Our experiences indicate that this wax stays on indefinitely.

With the top of the pay and the most permeable part sealed off then the next stage is to flood-out the next permeable part and the process is exactly the same. You then get another 2000 bbl. recovery after which you go in with more wax distillate and seal off the second stage. This now makes it economically possible for you to flood the third and harder parts so that your recovery is now, let us say, 6000 bbl. per acre instead of 2000 bbl.

All this is accomplished at a very slight cost of coring. Let us say this well does cost $850.00 to drill, the casing $350.00 more, or $1200.00, and the core costs $500.00, which is rather high. We have a total cost of $1700.00 for the first core and not only that, if the property can be developed we have a well that can be used as a water intake or an oil well if it is properly located, and our information has cost us about $500.00. Now with a problem like the one just outlined, or in fact if you do not have a problem, it is well to core a goodly number of wells throughout your entire development program. When you locate this well, locate it so that it can be used as either an oil or water well. On your 160-acre block you will either use 330 ft. from water to water, 440 ft. from water to water, or 330 ft. one side and 440 ft. on the other so it will not be any problem for you to lay out your property on one of these spacings and drill your well so it can be used. The spacing you select may not be the correct one but you can "fudge-in" and give and take a little bit on your other wells so that it can be used very nicely. In Pennsylvania we try to get the adjoining neighbor to join us in the cost of this well and put it right on the line between the two properties or preferably on the corner. Additional cores may be necessary but we are sure to obtain sufficient information from this one so we can determine where to locate the other core wells.

Suppose now that we have a sand with a permeability range that is entirely reversed from the one we just talked about, that is, the hard part of the sand on top, the middle section medium, and the lower section soft. You may have the same condition exactly, that is, you may think you are getting a good recovery and have a satisfactory operation, while in reality you may be losing two-thirds of your oil. In this case, after the lower and permeable streak is flooded-out, we would use cement. I told you under wax distillate to put in about one-half the amount you think will be required. What I should have further stated was that you put in about one-half and check the results, then keep adding quantities until you have effectively sealed the permeable streak. This is determined by the water intake. This same method holds true on the cementing job—play safe and put in somewhat less than you anticipate will be necessary to cover the permeable part. This can only be determined by cementing, and measuring and checking water intake. The same procedure holds true as in the reverse profile. You flood each stage successively and by using successive stages of cement you are able to recover three times more oil than had you not had the core.

Now we come to a condition that is more serious and not easily handled. Let us suppose we have a profile showing a soft streak in the center and harder parts on the top and bottom. In this case if our ratio of permeability from low to high is such that we cannot expect to recover any oil excepting from the permeable streak then we have to rest on that basis with the hope, however, that we can use compressed air to create a "Jamin" action. This has been successful in some cases. There has not as yet been developed any selective plugging agent that will work 100 percent. The condition illustrated is the one found less frequently.

From the foregoing, we have two chances out of three of correcting bad sand conditions and two out of three is not a bad ratio. The two out of three are definite and there is the possibility of even handling the third situation by the use of compressed air.

Well Spacing

This is not the only thing that core analysis will tell you. From the permeable profile it is possible to determine the maximum well-spacing that can be used in relation to the depth. The theoretical bottom-hole pressure possible to use for water repressuring is 1 lb. per ft. of depth. This, however, is theoretical only and twice this amount has been used. When excessive pressures are used, whether you believe it or not, the whole surface of the earth is lifted and the water by-passes through this crevice. In every instance, however, when the pressure is released, the earth goes back to its former position and the crevice is sealed and intakes go back to normal. It has been found through our research work carried on at Pennsylvania State College that the maximum pressure which can be used gives the greatest percentage recovery so that in all cases we calculate the maximum pressure and proceed from that point. Let us say, the well is 1000 ft. deep, then the hydrostatic pressure is about 450 lb. due to the weight of the column of fluid. We can theoretically add 500 lb. top-hole pressure and this is the pressure we would use in our calculations. In actual practice it may be possible to go to 2000 lb. bottom-hole pressure, which would allow us to put on the difference between 2000 lb. and 450 lb., or 1550-lb. top-hole pressure. This is stretching to the limit, however, and we prefer to keep as a cushion the difference between 550 lb. theoretical and, let us say, 1000 lb. practical in the event results are not too satisfactory with the lower pressure. The equipment would be purchased for 1000 lb. maximum. With the pressure known, it is then possible to calculate the most desirable well-spacing from the permeability profile. Let us suppose that we develop a property without the core analysis and that we are particularly fortunate in having a sand of

uniform permeability with none of the complications we have just outlined, but we have used 330 ft. well-spacing from water to water, which costs $1400.00 per acre development. Now let us suppose that this profile shows us we can use 440 ft. from water to water with a development cost of $1050.00 per acre, so we have saved $350.00 per acre on, let us say, 160 acres, or $56,000.00 development cost and all because we have taken some cores.

Now the question of well-spacing and the method of handling permeable streaks applies just as well to air and gas repressuring as to water, excepting that in the matter of well-spacing the calculations have not been developed insofar as I know to the same point of accuracy that has been done for water. It is, however, possible to determine an approximate spacing for gas repressuring that is very much better than the blind method of not knowing anything about the proper spacing to use.

Development Costs

We are now ready to check on our development cost accurately and try to develop a budget. The development cost is estimated by laying out the property completely to ultimate development, taking the cost of the water and oil wells to which is added pumping powers, pull rods, water plants, water lines, meters and all equipment. From this a cost per acre is determined and in turn a cost per bbl. The first year's development program is then laid out, and how do we determine how much we wish to develop? It may be determined by the amount of money available or it may be determined by the amount of crude desired. Let us say, for instance, it is the latter and we wish to produce 200 bbl. daily throughout the life of the property—200 bbl. per day times 365 days is 73,000 bbl. It is now necessary to estimate the rate at which this crude oil can be produced. Our rate in Pennsylvania for budget purposes is 40 percent the second year; we always allow one year for development to get the effects of the water, which is about six months' development and six months' water pressure. In the Mid-Continent this time can be reduced. All the figures that I have used or will use are simply approximate and intended to convey the thought. The third year 30 percent, fourth year 15 percent, fifth year 10 percent, and the sixth year 5 percent, completes a cumulative production curve. Therefore, the 73,000 bbl. we wish to produce in the second year is 40 percent of the oil that must be under flood, so that we have 182,500 bbl. that we must develop and if our core analysis as shown is 4000 bbl. per acre or 3500 bbl. net, then we must develop 182,500 bbl. divided by 3500 bbl. or 52 acres. You would develop to the nearest five-spot area to 52 acres and if things work out as you have anticipated you will produce during the next year an average of 200 bbl. per day and your estimated production schedule would look something like this: 30 percent the third year, 15 percent the fourth year, 10 percent the fifth year, and 5 percent the sixth year. Now then, we wish to produce 200 bbl. each year, so we have to make up so many bbl. during the third year. Using the same calculation, we determine that during the second year we must develop so many acres, and this same procedure is carried through until we arrive at a production schedule.

Now with these figures in mind we make our development budget and our first year shows so much for development. We figure practically no production, so we throw all the operating expense into our development or if you prefer set up a reasonable amount for this item. To this you add your overhead, taxes, interest, and come out with your expenditures for the year and, bear in mind, practically no income. We do the same thing the second year, the third, fourth, and fifth years and so on and carry cumulative cash balances at a line on the bottom so that before we are through we have a complete development budget over the life of the property, with the only unknown factor of price. It seems to me that in this area you can use one dollar per bbl. as an average price over 15 years and you can be justified in doing so. From this you can, of course, determine whether you have or have not a profitable operation, but before you do all this the rough method that I outlined at first is the proper one to use. With our complete development cost known we add operating at so much per bbl. dependent upon the depth and which is pretty well established by experience, and our thought is that it will range from 25 cents per bbl. at 1000 ft. to 45 cents price per bbl. at 2000 ft. You know what your first year's development cost will be so you add interest at whatever price you have to pay and carry on your interest charges throughout the period the money is owed. You know how many barrels per acre recovery you expect to get at so much per bbl. and it is a very easy calculation to determine if it is or is not a profitable operation.

Cores Essential

If I have learned anything from 25 years in the oil business, most of which has been operating stripper wells excepting the last two or three years when it has been necessary for us to stretch out because of the liquidation of all our water-flood properties in the Bradford field, it is to spend your money for cores before spending money for acquisition or development of property.

Value of Research

Several years ago I suggested to the Independent Petroleum Association of America the establishment of a division that would have for its purpose the study and improvement of secondary recovery methods. I now believe that instead of the Independent Petroleum Association, the National Stripper Well Association is such an organization to sponsor such a movement. A research program has been carried on at Pennsylvania State College since 1933. Since that time the research staff has increased from one man until there are seven men now engaged in the study of secondary recovery by water-flooding. Part of the funds have come from the association and part from the state.

The procedure I have outlined has been made possible by the work of this research group. First it was permeability, then the proper use of high pressure, the ability to calculate bottom-hole pressure requirements in relation to over-burden, and to calculate the amount of water intake and the length of time to reach the peak of production. Research work has been done on shooting and selective plugging and many, many dollars and much time have been spent in an effort to develop a chemical that will increase the recovery per acre. Quite a large number have been found but none of them has proven entirely satisfactory. My suggestion to you is that you sponsor a research project in each state college or university that has a petroleum course or rather, the leading state college or university that has a petroleum course, and get the State to appropriate direct a sufficient amount of money to get started on this study. As I remember it, the State of Illinois even goes so far as to help in taking cores, furnishing the core barrel, and analyzing the cores. This is perhaps the most generous treatment of producers in any state that I know of. If you can get your universities or colleges through state sponsorship to start a research program, then you will go a long way towards solving the local problem, which must at times be different from those in Pennsylvania, Illinois, or any other state. It seems to me the possibilities are unlimited if this is carried through to conclusion.

The Compressibility of Gases

III. Measurement of gas flow under pressure

By GEORGE GRANGER BROWN

Professor of Chemical Engineering, University of Michigan

ACCURACY in gas measurement is a most important requirement, which can be satisfactorily met only by a thorough appreciation of the fundamental factors involved and the assumptions made. The measurement of gas flow in the natural gas and gasoline industry is usually made by means of the sharp edge orifice meter because of its simplicity, low cost, and accuracy when properly used. For a thorough understanding of the orifice meter it is necessary to begin with the basic flow equation derived by an energy balance around the flow system.

Consider, for example, any flow system such as that indicated in Fig. 5 representing any fluid in continuous flow. The fluid may be more dense than the surrounding atmosphere as in the case of water or gas under high pressure, or the fluid may be less dense than the surrounding atmosphere as natural gas at low pressure. The flow system may include engines or coolers, which remove energy from the fluid; pumps, compressors, or heaters, which put energy into the fluid, or any combination of such devices, provided only that the fluid is in continuous flow so that the same quantity of fluid in pounds enters the flow system at point 1 as leaves the flow system at point 2 during any period of time. Under these conditions the energy brought into the flow system with each pound of fluid entering at point 1 plus the energy added to each pound of fluid and minus the energy removed from each pound of fluid as it flows from point 1 to point 2 must equal the energy carried out of the flow system with each pound of fluid as it leaves the flow system at point 2.

$$E_1 + P_1V_1 + h_1 + \frac{u_1^2}{2g} + Q - w_s - w_f = E_2 + P_2V_2 + h_2\frac{u_2^2}{2g} \quad . \quad . \quad . \quad (11)$$

where

E = internal energy of 1 lb. of fluid including all energy possessed by the fluid except that energy due to its condition of flow, such as kinetic energy and energy of position

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PV = pressure times volume (or force times distance); the mechanical energy carried by 1 lb. of fluid due to its condition of flow

h = potential energy; the energy carried by 1 lb. of fluid due to its position in the gravitational field

$\frac{u^2}{2g}$ = kinetic energy ($\frac{1}{2}$ mu^2 if m = mass, u = velocity, and mg = weight) carried by 1 lb. of fluid due to its velocity in flow

Q = heat added to 1 lb. of fluid while in flow between points 1 and 2

w_s = "shaft" work contributed by 1 lb. of fluid as in driving an engine while flowing from point 1 to point 2

w_f = energy expended by 1 lb. of fluid in overcoming friction while flowing from 1 to 2.

Subscripts refer to the position in the flow system as indicated in Fig. 5.

For a heavy fluid such as water, in which case the buoyant action of the surrounding air can be neglected, the increase in potential energy,

$$\Delta h = h_2 - h_1,$$

is equal to the increase in elevation as indicated by $\Delta X = X_2 - X_1$ in Fig. 5; and the corresponding increase in pressure, ΔP, required to balance this increase in "head" is:

$$\Delta P = \rho \Delta h = \rho \Delta X$$

where

ρ = specific weight of fluid, lb. per cu. ft.

P = pressure, lb. per sq. ft.

In the case of lighter fluids, where the buoyant action of the atmosphere may not be neglected, the increase in potential energy is:

$$h_2 - h_1 = \Delta h = \Delta X\left(\frac{\rho\ (\text{fluid}) - \rho\ (\text{atmos.})}{\rho\ (\text{fluid})}\right). \quad (12)$$

and the corresponding increase in pressure is:

$$\Delta P = \rho_f \Delta h = \Delta X\ (\rho_f - \rho_a) \ . \quad (13)$$

If the specific weight of the fluid is less than that of the surrounding atmosphere the potential energy of the fluid decreases as the elevation is increased. Such considerations are important in the flow of gases at low pressures as in city distribution systems and industrial furnaces but are usually unimportant in handling gases under pressure as the effect of potential energy is so small relative to the pressures available, that these terms may be neglected.

From the first law of thermodynamics (conservation of energy), the heat absorbed by the fluid, Q, must equal the sum of the increase in internal energy, ΔE, plus the energy expended as work. In the case of a fluid such as natural gas undergoing no changes other than heat and compression:

$$Q = \Delta E + \int PdV \quad . \quad . \quad (14)$$

Substituting in equation (11):

$$-\int PdV + P_2V_2 - P_1V_1 + h_2 - h_1 + \frac{u_2^2 - u_1^2}{2g} + w_s + w_f = 0$$

$$P_2V_2 - P_1V_1 = \Delta(PV) = \int d(PV) = \int PdV + \int VdP$$

$$-\int PdV + \int PdV + \int VdP + \Delta h + \Delta\frac{u^2}{2g} + w_s + w_f = 0$$

$$\int VdP + \Delta h + \Delta\frac{u^2}{2g} + w_s + w_f = 0 \quad . \quad . \quad . \quad . \quad . \quad . \quad (15)$$

For continuous flow where A=cross-sectional area of flow passage:

$$\frac{A_1u_1}{V_1} = W = \frac{A_2u_2}{V_2} \quad . \quad . \quad . \quad . \quad (16)$$

where

u = avg. linear velocity, ft. per sec.

V = specific volume, cu. ft. per lb.

W = lb. flowing per sec.

For horizontal flow with no work done, $\Delta h = 0$, $w_s = 0$, $w_f = 0$, as for an orifice in a line, and with $PV^n = C$, where n has the proper value to represent the path followed by the fluid in flow, from equation (15):

$$-\int_1^2 VdP = \frac{n(P_1V_1 - P_2V_2)}{n-1} = \frac{nP_1V_1\left(1-\frac{P_2}{P_1}\right)^{\frac{n-1}{n}}}{n-1} = \frac{u_2^2 - u_1^2}{2g}$$

. . . . . (17)

Substituting $\frac{WV}{A}$ for u as from (16):

$$\frac{u_2^2 - u_1^2}{2g} = \frac{W^2}{2g}\left[\left(\frac{V_2}{A_2}\right)^2 - \left(\frac{V_1}{A_1}\right)^2\right] = \frac{W^2V_2^2}{2gA_2^2}\left[1 - \left(\frac{A_2}{A_1}\right)^2\left(\frac{P_2}{P_1}\right)^{\frac{2}{n}}\right] \quad (18)$$

Combining (17) and (18) and solving for W:

$$W = A_2\sqrt{\frac{2gn}{n-1}\frac{P_1}{V_1}\left[\left(\frac{P_2}{P_1}\right)^{\frac{2}{n}} - \left(\frac{P_2}{P_1}\right)^{\frac{n+1}{n}}\right]\frac{1}{1-\left(\frac{A_2}{A_1}\right)^2\left(\frac{P_2}{P_1}\right)^{2/n}}} \quad . \quad (19)$$

Equation (19) is a general theoretical equation applicable to the flow of fluids through horizontal pipes, orifices, etc. as indicated in Fig. 6. It can usually be simplified in special cases.

For Small Pressure Differentials

If the pressure drop is extremely small so that the specific volume of the gas is constant, $n = \infty$ and the equation becomes:

$$W = A_2\sqrt{2g\frac{(P_1 - P_2}{V} \times \frac{1}{\left(1-\frac{A_2}{A_1}\right)^2}}$$

. . . . . (20)

In actual use the cross-sectional area of the orifice, A_0, is used instead of the contracted area of the fluid, A_2, at the "vena contracta" as indicated in Fig. 6, and a factor, K′, is used to correct the equation for friction losses and for this substitution of areas:

$$W = \frac{K'A_0\sqrt{2g}}{\sqrt{1-\left(\frac{A_0}{A_1}\right)^2}}\sqrt{\frac{P_1 - P_2}{V}} \quad (21a)$$

For any particular orifice this may be further simplified as:

$$W = KA_0\sqrt{\frac{P_1 - P_2}{V}} \quad . \quad . \quad (21b)$$

where K is a function of the pipe and orifice diameters, of the mechanical setting of the meter run, of the pressure connections, and of the velocity and viscosity of the gas.

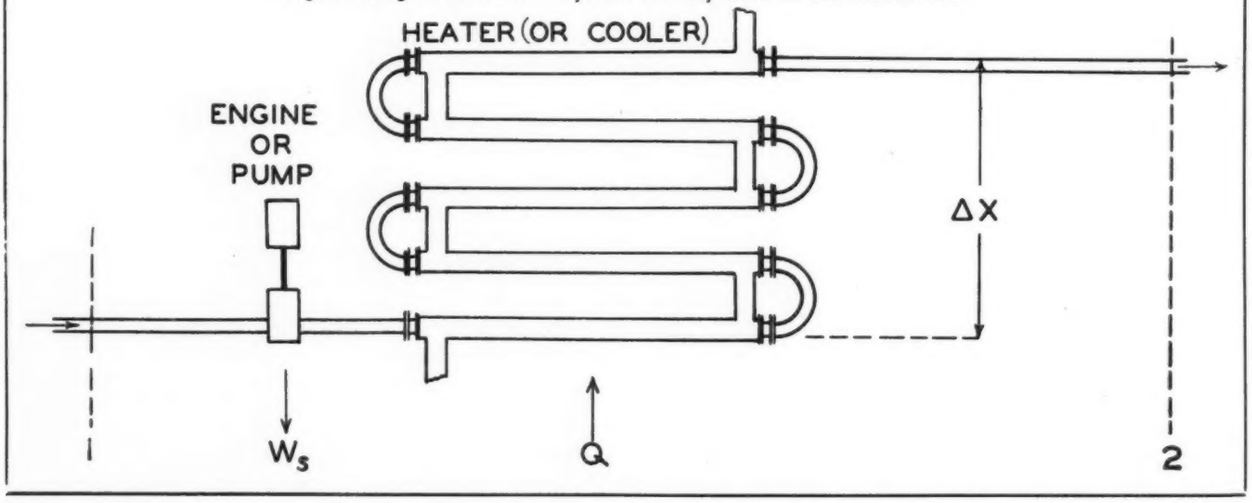
The value of $\sqrt{\left(1-\frac{A_0}{A_1}\right)^2}$ is very close to unity, being 0.96825 when A_0/A_1 is 0.25, or the diameter ratio of D_0/D_1 = orifice diameter ÷ pipe diameter is as large as 0.5. This factor may be, and usually is, omitted, therefore, with the effect of making the meter reading somewhat low.

It is of course possible to make some compensating adjustment in the value of K′ or K when the diameter ratio is large. To a limited extent this is done in commercial practice so that the meter reading is usually not more than 2 or 3 percent low because of this practice.

The effect of the velocity and viscosity of the gas on the friction loss in the orifice is relatively small and usually neglected. This leaves the value of K′ simply a function of the diameter ratio $\left(\frac{D_0}{D_1}\right)_1$, the mechanical setting of the meter, and the position of the pressure connections; with the meter reading accurate within about 3 percent.

In determining the flow of gas, it is customary to express the result in standard cu. ft. (as measured at 60°F. and 14.65 lb. per sq. in. abs.) per day, or per hr., rather than in lb. per sec. The drop in pressure, $(P_1 - P_2)$, is frequently expressed in in. of water, or in. of mercury, instead of in lb. per sq. ft.

Fig. 5. Diagrammatic flow system for any fluid in continuous flow



$$PV = ZNRT \quad . \quad . \quad . \quad . \quad . \quad (4)$$

from which the specific volume at any condition of T, and P, is: $V = \frac{ZRT}{MP}$

Making these substitutions in equation (21):

Std. cu. ft./hr. (at $T_s P_s$) =

$$K' \frac{Z_s R T_s}{M P_s} \times \frac{3600\, A_0 \sqrt{2g}}{\sqrt{1-\left(\frac{A_0}{A_1}\right)^2}} \sqrt{\frac{(h_1 - h_2)_w \, 62.4}{V \quad 12}} \quad . \quad . \quad (22)$$

where

$(h_1 - h_2)_w$ = differential pressure, in. of water

M = molecular weight of gas

V = specific volume of gas at temperature and pressure of measure-measurement.

Equation (22) may be simplified with the omission of $\sqrt{1-\left(\frac{A_0}{A_1}\right)^2}$ taking Z_s equal to unity for atmospheric pressure, and substituting as follows:

Std. cu. ft./hr. (at $T_s P_s$) =

$$K' \frac{T_s}{P_s} \times 3600\, A_0 \sqrt{2g} \sqrt{\frac{62.4}{12}} \sqrt{R} \sqrt{\frac{(h_1 - h_2)_w P}{MZT}}$$

$$= 2{,}588{,}659\, K' A_0 \frac{T_s}{P_s} \sqrt{\frac{(h_1 - h_2)_w P_2}{MZT_1}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (23)$$

Frequently the "coefficient" also includes the values for M and T so that the gas flow is determined by the equation:

Std. cu. ft. per hr.=

$$C \sqrt{\frac{(h_1 - h_2)_w P_2}{Z}} \quad . \quad . \quad . \quad . \quad (24)$$

If the meter coefficient is expressed as in equation (24), the value for Z is frequently assumed to be equal to unity, as for ideal gases. In order to obtain the correct reading in such cases it is necessary to include the correct value for Z, or multiply the meter reading obtained from the ideal gas laws, by:

$$\sqrt{\frac{T_s}{T}} = \sqrt{\frac{460 + t_s\,°F.}{460 + t\,°F.}}$$

where

T_s = absolute temperature used in determining the value for C in equation (2)

T = actual absolute temperature of gas being measured.

Similarly if the "coefficient" also includes the molecular weight, or the specific gravity of the gas being measured, a correction must be made by multiplying the values obtained from equation (24), or its equivalent, by:

$$\sqrt{\frac{M_s}{M}} = \sqrt{\frac{(Sp.\ gr.)_s}{(Sp.\ gr.)}}$$

where

M_s = molecular weight used in determining C in equation (24)

M = actual molecular weight of gas being measured

$(Sp.\ gr.)_s$ = specific gravity used in determining C in equation (24)

(Sp. gr.) = specific gravity of gas being measured.

Pressure Differentials to One-Fifth Absolute Pressure

In the use of equations such as (24) for appreciable drop in pressure through the orifice, the pressure, P, should be the pressure of the gas passing through the orifice, or P_2 in Fig. 6. Commercial meters are usually constructed to record the downstream pressure, P_2. If not, P_2 may be obtained by subtracting the pressure drop through the orifice from P_1, the upstream pressure. The temperature, T, should be the upstream temperature. These same values for P_2 and T_1 should also be used in evaluating Z from Fig. 1 or 4 as has been explained. When used with these values and with the corrections indicated in equations (23) and (24), the meter reading is somewhat high, but not more that 1 percent, provided P_2/P_1 is not less than 0.8, or the pressure differential through the orifice is not greater than 20 percent of the absolute pressure upstream, and the diameter of the orifice is not more than one-third that of the pipe. As the usual calibration of an orifice meter is low, tolerating errors to 3 percent by neglecting

$$\sqrt{1-\left(\frac{A_0}{A_1}\right)^2}$$

in equation (21), this error of 1 percent on the high side tends to compensate. It is clear, therefore, that the procedure using equations (23) or (24) and the compressibility factor Z as outlined, (introducing as it does, less than 2 percent error), is suitable for most present engineering requirements for the measurement of natural gases under pressure in properly installed meter runs.

Sample Calculation for Orifice Meter

The orifice coefficient used by most manufacturers is derived from equation (23). Foxboro Company, for example, gives:

Std. cu. ft. per hr. =

$$218.44 K' D_0^2 \frac{T_s}{P_s} \sqrt{\frac{(h_1 - h_2)_w P_2}{T_1\ (sp.\ gr.)}}$$

. . . . . (25)

where

P_s = standard pressure, lb. per sq. in. abs.

P_2 = absolute downstream pressure in lb. per sq. in.

D_0 = orifice diameter, in.

K′ = orifice efficiency, a function of the diameter ratio, $\frac{D_0}{D_1}$

Z is assumed to be unity.

The hourly coefficient, C, in equation (24) as used by Foxboro for the number of standard cu. ft., at 60°F. and 14.65 lb. per sq. in. absolute, flowing per hr. through a 2½-in. diameter orifice in a pipe having an inside diameter of 6 in. or greater when P_2 is in lb. per sq. in. and for a gas of 0.6 sp. gravity (17.4 molecular wt.) is given as 1663. If the pipe diameter is smaller so that the diameter ratio D_0/D_1 is less than 0.41, a larger coefficient is used. The "efficiency" of the orifice (K′ in equation 25) is given as 0.606 for all meter settings where $D_0/D_1 < 0.41$. For larger diameter ratios:

K or E =

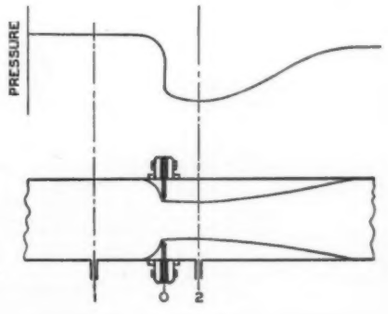
$$0.606 + 1.25\left(\frac{D_0}{D_p} - 0.41\right)^2. \quad (26)$$

To find the correct coefficient, therefore, to use with a 2½-in. orifice in a meter setting where the pipe diameter upstream from the orifice is 4.906 in., the correction due to the effect of pipe diameter on the orifice efficiency, from equation (26), is:

$$\frac{0.606 + 1.25\left(\frac{2.5}{4.906} - 0.41\right)^2}{0.606} = \frac{0.6184}{0.606}$$

The hourly coefficient for 60°F. and gas of 0.6 sp. gr. is:

Fig. 6. Diagrammatic sketch of an orifice meter



$$C = 1663 \times \frac{0.6184}{0.606} = 1697$$

If the flow conditions and gas properties are as follows:

Actual flow temperature = 70°F.

Downstream pressure, P_2 = 736 lb. per sq. in. abs.

Sp. gr. of gas (air = 1) = 0.667

Pseudo-critical pressure = 669 lb. per sq. in. abs.

Pseudo-critical temperature = 377°R. or —83°F.

Pressure differential = 38.5 in. water

$$\text{Pseudo-reduced pressure} = \frac{736}{669} = 1.10$$

$$\text{Pseudo-reduced temp.} \frac{530}{377} = 1.41$$

Compressibility, Z, from Fig. 4 = 0.862, then the correct rate of flow in std. cu. ft. per hr. is:

$$1697 \sqrt{\frac{38.5 \times 736}{0.862}} \sqrt{\frac{520}{530} \times \frac{0.60}{0.667}}$$

= 289,000 std. cu. ft. per hr.

Errors. The importance of avoiding bends and any obstructions that might introduce eddies in the flow through the orifice is generally appreciated. But greater errors may be introduced by other conditions frequently encountered.

Pulsations. Serious errors may be introduced by pulsating flow, as exists in lines connected to gas compressors. These errors are caused by the differential manometer, or other recording device, across the orifice indicating approximately the arithmetric mean differential pressure whereas the flow varies with the mean square root of the differential pressure. The result is that the recorded differential pressure is too great for the actual flow, causing the meter to read high. This is true even if the manometer taps are throttled so that the indicated differential pressure appears reasonably constant.

These errors may be caused by a pulsation in pressure waves traveling through the fluid with a velocity equal to that of sound relative to the fluid, and by traveling pulsation in the velocity of the fluid itself.

The error due to pressure variation may be reduced by taking pains to have the pressure lines leading to the meter of equal coefficients of discharge for inflow and outflow and the capacity in the lines and meter the same on each side of the mercury or water column.

The error due to velocity variation cannot be eliminated by any meter construction now available. It varies with many factors and the best plan is to reduce the variation to a minimum as there is no satisfactory manner of making proper corrections.

The approximate error caused by pulsation in the velocity as reported by Hodgson[1] is indicated in Fig. 7 as a function of the product:

$$\frac{CpF}{PVW}$$

where

C = the volume capacity in the line in cu. ft. between the source of pulsation and the meter

p = the pressure drop in lb. per sq. ft. between the entrance to the capacity, C, and the side of the orifice or venturi meter which is farthest from the source of pulsation

F = the frequency of pulsation per sec.

P = absolute pressure, lb. per sq. ft.

V = specific volume of fluid, cu. ft. per lb.

W = weight rate of flow in lb. per sec.

As indicated by a study of Fig. 7, the large error due to pulsation in velocity frequently found in gas lines leading to or from compressors, can often be reduced to a negligible factor (under 3 percent) by increasing the capacity of the line between the meter and the source of pulsation, and increasing the pressure drop between the source of pulsation and the far side of the meter.

For this reason small orifices, which have larger pressure drops, are affected less by velocity pulsations than large orifices with smaller pressure drops.

A high frequency, F, in pulsation also introduces less error than a low frequency. A single compressor giving a low frequency of pulsation will cause a greater error than a battery of compressors giving a high frequency.

In making an installation to reduce errors due to pulsation, the capacity should be inserted between the source of pulsation and the metering point. If the meter itself does not offer sufficient resistance, an additional throttling device may be added downstream.

A mercury manometer appears to show less error than a water manometer, and the presence of a check valve or damping device between the chambers in the two manometer legs may be of help. Mufflers in the main line, or capacity or throttles in the meter pressure lines seem to be of no benefit. And it is impractical to apply satisfactory corrections for pulsations as the error varies widely and may be very large.

Condensate or Two Phases Present

The presence of any condensate or liquid in the gas will cause errors in the use of these equations as there is no way of determining the average density of the material flowing through the meter. Care should always be taken to insure that the gas is dry as it enters the meter run and that no condensation occurs therein.

If liquid and gas are flowing through the same line and the combined stream is to be measured, the gas can be separated from the liquid and each phase measured in its own meter by flowing the separated gas through a gas meter and the separated liquid through a liquid meter and recombining the two streams downstream if so desired.

[1]Trans. A.S.M.E. *44*, 904 (1922) also FSP-51-42.

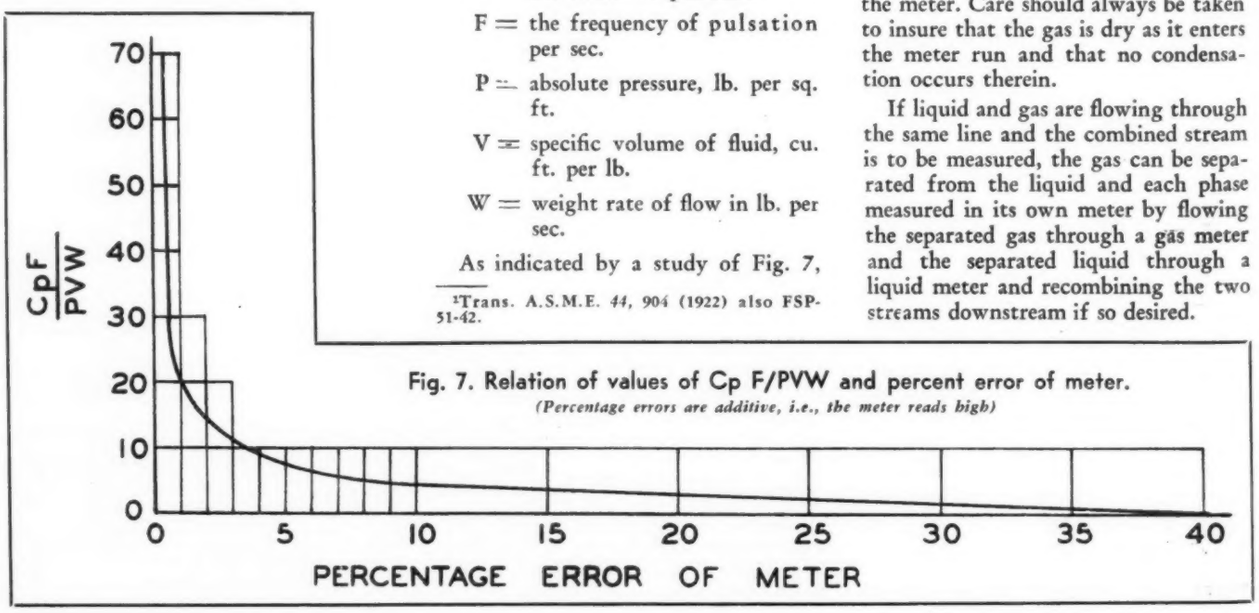


Fig. 7. Relation of values of Cp F/PVW and percent error of meter.
(Percentage errors are additive, i.e., the meter reads high)

P 514.311

Zinc Guides Reduce Electrolytic Pitting of Sucker Rods

Pure pig zinc cast-on rods in pumping wells serves to "feed" galvanic currents and thus protect the steel in the rods from pitting

By H. LEE FLOOD
Associate Editor

A PROBLEM that is generally recognized as one of the most important with which the production engineer is faced is the elimination, or at least the reduction in frequency of breaks in sucker-rod strings in pumping wells. In this connection, tests of zinc rod guides being made by one of the larger producing companies in the West Texas area are noteworthy.

The results in West Texas are interesting, not because the use of zinc guides is new, but because more gratifying results are being attained probably than in earlier tests made in other areas, notably in Arkansas by one of the companies operating in that state.

A tedious discussion of the principles involved is purposely avoided in describing the use of zinc as a means of protecting the steel in the sucker rods from the harmful action of electrolysis. Zinc, being higher in the electromotive series than iron or any of the other metals in the alloy steels used in sucker-rod manufacture, should be and is attacked more readily by electrolytic currents. Molded on the rods at intervals as guides, the zinc, therefore, serves to "feed" the current rather than permitting the discharge of current and the resultant pitting to occur from and in the steel of the rod itself.

Prior to the first installations of zinc guides in West Texas about a year and a half ago, it had been suspected for sometime that the deep pitting occurring in the sucker rods of pumping wells was caused by electrolytic action. In wells where the action was more severe, nearly all were producing large volumes of water with the oil. It appeared probable that the currents causing the trouble were being generated by the immersion of two dissimilar metals in this water; either the rods and tubing, the tubing and casing, or even different parts of the rod string itself. This is only one of the theories that might account for the generation of currents, and is mentioned here only to record the sequence of thought leading to the use of the zinc guides.

Various methods had been tried to combat the trouble even before zinc was used. Wrought iron was introduced as a possible remedy a few years ago but in most instances small benefit was derived. It is generally agreed now that this was only a wrong application of a wrought metal and not necessarily a condemnation of its value in other services. Various alloys were then tried, in which the content of nickel was gradually increased during the course of the tests. Results were no more encouraging than when wrought iron was used, but all observations supported more strongly the belief that currents were being generated within the rod itself.

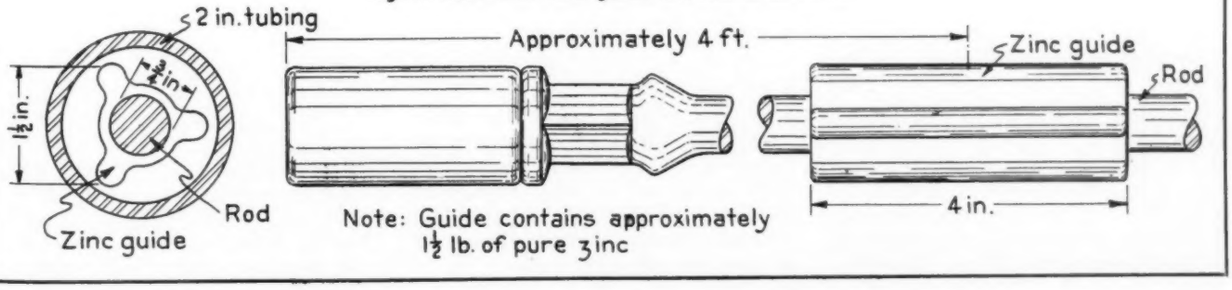
It was known that zinc had been used off and on for years in pumping wells, either to combat electrolysis or to mitigate the conversion of chlorides and sulphides into harmful acids. Previous experience with zinc had not been successful, however, largely because attack of the metal would cause flakes of zinc to enter and damage the pump by scoring or otherwise damaging its working parts. It has been reported that these earlier experiments were made with a zinc alloy rather than with pure zinc and that the flaking was caused by the corrosion of the other metals in the alloy first, permitting the zinc to flake and cause damage. Other reports indicate, however, that pure pig zinc was used earlier but that even then certain minute particles of the metal would be more susceptible to attack than others, thus also resulting in flaking. It has been stated that probably these earlier tests of zinc guides were unsatisfactory because they were not watched closely rather than because of anything else.

Results in West Texas

In planning the tests in West Texas, two general points were stressed: (1) pure pig zinc would be used, and (2) the behavior and condition of the zinc guides would be observed closely by pulling the rods at frequent intervals.

The initial installation was made in a well designated here as "A", in which rod breakage had always been quite severe. For example, on September 4, 1938, well "A" was worked over, and equipped with a reconditioned string of sucker rods, of which the top 625 ft. was new ⅞-in. stock. The first break in the new rods occurred after 53 days of operation. Thereafter, until December 15, 1938, the frequency of rod breaks averaged 3.7 days. On the latter date, a 1000-ft. section of new ⅞-in. rods (from the same shipment as the 625-ft. section) was installed in the well. On every other rod, a zinc rod guide had been cast, formed on the rod approximately four ft. from one end, as shown in Fig. 1. Care was taken to not alter any other conditions in the well. Other equipment and the

Fig. 1. Sketch of zinc guide cast-on sucker rod



stroke and motion of the pumping unit remained unchanged.

With the guide-equipped string in service, the first break occurred after 197 days of service. If comparison is made with the 625-ft. string in the well just prior to the test, the additional 144 days of service before the first break may be attributed to the zinc guides, if all other possible contributing factors are assumed equal. The second break in the string with guides occurred after 258 days of service, the third break after 305 days, the fourth after 320 days, and the fifth and sixth breaks had occurred before 350 days of service had been attained.

The frequency of breaks in both strings has been plotted in Fig. 2 to show the increased service obtained from the string equipped with the guides.

That the use of zinc guides is definitely not a cure-all for all rod failures, assuring unlimited life to a string, is indicated in Fig. 2, following the seventh break in the guide-equipped string. The five breaks (seventh to eleventh inclusive) occurred in less than a month's time (during January, 1940). It is evident that the other causes of rod failure (metal fatigue, hydrogen embrittlement, and so on) had begun to appear at this time.

On the basis of this one test, inconclusive as it is, a rather definite economic life is indicated for rods in this well—either following the sixth break or after approximately 360 or 380 days.

Postponement of the first break in the string equipped with guides was probably aided by the replacements made during the three inspections. A break in the older rods on January 18, 1939, at a depth of 1225 ft. (below the new rods being tested) afforded the first opportunity to inspect the guides. Even after only 34 days of service, the zinc disclosed definite evidence of being consumed by electrolysis.

On March 3, 1939, the rods were pulled in order to observe the condition of the guides. It was found that electrolytic deterioration of the guides was proceeding uniformly at a slower rate than had been anticipated. Inspection of the rod surfaces failed to show any pitting in the steel. Three of the guides, however, were found to be worn excessively by abrasion and were replaced prior to running the string back in the well. The worn guides were then broken-off and new guides cast on the rods to serve as future replacements.

Another inspection was made on May 14, 1939. At this time it was found that the guide on the 36th rod had worn through and was about to drop off. The guide on the 34th rod was badly worn and showed evidence of heavy electrolytic action. Three pits

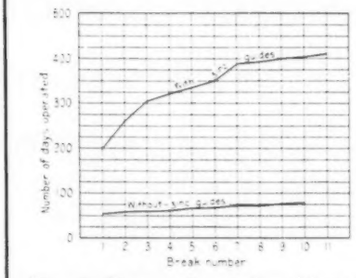


Fig. 2. Comparison of rod-break frequency in well "A"

resulting from electrolysis were found on the surface of the 34th rod. Attack of the zinc by electrolytic current was evident on all 20 guides installed in the 1000-ft. section, the worst being at depths of 750 to 1000 ft. The guides on the two rods discussed were replaced and the string was again put in service.

The total length of the rod string in well "A" is 2200 ft. The well is equipped with 3-in. tubing and a 3-in. common steel pump. The well produces 18 bbl. of oil and 800 bbl. of water, pumping at the rate of 22-54-in. s.p.m. Maximum load is 8400 lb.

Two other wells in West Texas, equipped with zinc guides subsequent to the initial installation just described, are being tested at the present time.

One of these, well "B", was equipped on April 20, 1939, with 475 ft. of new ¾-in. rods having zinc guides cast on alternate rods. This section replaced a 500 ft. section of plain rods (without guides) that had been installed on September 9, 1938. In the 224 days of service obtained from this string, 20 breaks occurred at an average frequency of 11.2 days. Forty-seven days prior to the installation of the guides, the 2-in. plunger pump had been replaced by a 2½-in. pump having a 4-cup traveling valve. The first break in the guide-equipped string occurred after 108 days but examination of the break indicated that a V-notch resulting from a tool mark had caused the weak point. Since that time, no other breaks have occurred in the test section to date. Well "B" is pumping 20 bbl. of oil and 170 bbl. of water through 2-in. tubing at a speed of 18-24-in. s.p.m. This is a light well having a maximum polished-rod load of 8030 lb.; minimum load is 3850 lb.

Well "C", the only test in which zinc guides have been installed on 1-in. rods, was equipped with 500 ft. of new 1-in. rods on which zinc guides were cast. This string replaced a 500 ft. string not protected by guides, that had experienced its first break after 58 days' service and in 101 days had suffered 7 breaks, an average frequency of 14.4 days between breaks.

First break in the guide-equipped string in well "C" occurred after 304 days service. Examination showed the failure began in a small pit; the removed rod showed scattered small pits believed to have been caused by galvanic action. The broken rod had no guide but the ones just above and below were equipped with guides. Well "C" is a heavy well, having a maximum polished-rod load of 14,300 lb., a minimum of 660 lb. The well produces 22 bbl. of oil and 1100 bbl. of water using a 4-in. casing pump.

Casting Zinc Rod Guides

Two precautions are necessary in assuring successful casting results: (1) the rod surface must be cleaned to insure a satisfactory contact between the zinc and the steel, and (2) the rod and mold must be preheated.

The molds used were obtained from one of the zinc producers operating in the mining area of northeastern Oklahoma, as is the pure pig zinc used in the work. The shape of the mold is designed to permit passage of the fluid around the guide and still retain strength in the guide.

Some dissatisfaction has been expressed with the bond obtained by only filing or otherwise cleaning the rod surface preparatory to casting the zinc. The use of acid is contemplated as a means of cleaning the rod but this is a practice that should be used with extreme caution. A strong acid applied for too long a period might impair the strength of the rod.

Conclusion

The results of the work in West Texas, though by no means conclusive, are sufficiently encouraging to warrant further use. It should be stressed that the results, on the whole, are more successful than any others known and it is possible that application elsewhere might not achieve favorable results.

As a result of the experience in West Texas, the company conducting the tests has concluded that the use of zinc guides is worthwhile but it plans to continue their use only as a last resort in wells giving the greatest amount of trouble. It has been established that proper use of the guides makes it mandatory that frequent inspections be made. Unless an operator is willing to pull the rods frequently, even when there is no reason to do so other than to inspect the guides, the use of guides is not recommended.

Present experiments with zinc guides are by no means limited to the West Texas area. Other companies are testing their value under various conditions. It is hoped that additional data, as they become available, will be presented by the companies conducting the tests.

High Rotary Speeds in California Drilling

Speeds as high as 750 r.p.m. have been used—as much as 1080 ft. of hole has been drilled in 9 hours—rock bits used almost entirely in high-speed operations

By WALLACE A. SAWDON
Pacific Coast and Foreign Editor

HIGH rotating speed has been so successful in drilling straight, fast holes to depths of 10,000 ft. and more in the San Joaquin Valley, California, that it has practically established a new drilling technique. Rock bits have been used for almost all the footage made with fast table speeds and are particularly adaptable to the formations that have been drilled in both the proved fields and in wildcat wells where speed of rotation ranges from 350 to 750 r.p.m.

Although both Union Oil Company and Superior Oil Company are using consistently high speeds in drilling, Union has employed the highest speeds and the technique here described is that developed by J. E. Reed, drilling superintendent for Union Oil Company in the San Joaquin Valley. Until recently, rotating speeds greater than 500 r.p.m. had to be estimated because of the limit of the mechanical type of tachometer used to indicate the speed; but the Union wells are now being equipped with electrical tachometers that will register to 700 r.p.m. In many instances, however, even the 700 r.p.m. speed is exceeded and it is only by close estimation that the maximum speed of rotation yet used has been placed at approximately 750 r.p.m.

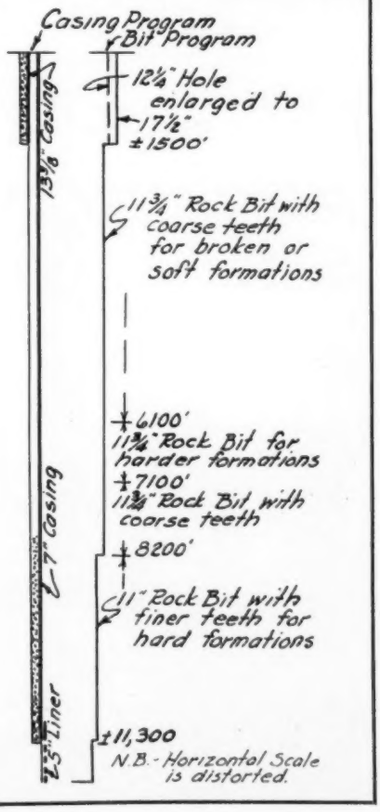
The object of high rotating speed is to drill a fast, straight hole and to put down a deep well with least cost and minimum trouble. Considerable importance is attached to the verticality of the surface string and every care is taken to make this string as straight as possible. When 13⅜-in. pipe is to be run, a 12¼-in. bit is used to drill to the landing point and the hole is then enlarged to 17½-in. Although drag bits are sometimes used for top digging, rock bits frequently drill the entire hole from grass roots down. The 12¼-in. hole is enlarged by means of a hole opener on top of which is placed a reamer. In starting the hole the speed is retarded until the drill collar is buried, then rotation is increased. The surface string is generally 1500 ft. in length and the time required to enlarge this amount of hole from 12¼ in. to 17½ in. is approximately nine hours.

After passing from the surface string the highest rotating speed is attained. Nearly a year ago a top speed of 575 r.p.m. was used in drilling a wildcat well with a drilling speed record that was exceptional.[1] Since that time speeds have been increased and the highest used to date has been 750 r.p.m.

The practice being followed is to rotate fast until the top of the kelly is near the table. The rotating speed is then slowed down and another foot of hole made with slow rotation. After adding another stand of pipe the bit is set on bottom and rotation begun slowly to make sure the cones are turning. The table is then speeded up and the procedure repeated. The reason for slowing down rotation for a short time before breaking connections is to allow the bit to cool. Otherwise the heat generated in the bit by the high-speed rotation would force all water from the mud and bake it in and around the bit to such a degree that the cutter would be frozen on the bit and would not turn.

[1] "High Rotating Speeds Employed in Drilling Deep California Well," by W. A. Sawdon, *The Petroleum Engineer*, July, 1939.

Fig. 1. Types of rock bits used for high rotating speed at various depths



There is a critical speed of rotation at which the pipe vibrates. This speed depends on the weight being carried on the bit and on the formation being drilled. For drilling with high-speed rotation there must be enough power available in the drilling equipment to pass above the critical speed. Pipe vibration sometimes occurs, however, from other causes. In such cases rotation is stopped and then started again, usually with satisfactory results. In other cases the fault is with the mud; a drilling fluid of too low viscosity may cause the drill pipe to vibrate. This is remedied by thickening the mud. A very small crook in the drill pipe will also cause the drill string to vibrate or whip and particular care is taken to keep drill pipe straight when it is being used for high-speed rotation.

Rock bits with different types of cones are used at different depths and in general those with coarser teeth are employed for upper drilling and those with finer teeth for deeper hole. At Rio Bravo, cones suitable for broken formation are used to depths of approximately 6100 ft. From there to 7100 ft., the formation is harder and a bit is used having teeth better suited for digging in this type of rock. The same kind of bit as used for the upper formations is employed for drilling the next 1100 ft.; but from approximately 8200 ft. to bottom, a finer-tooth bit designed for drilling comparatively hard formations is used.

No bit less than 11-in. diameter is used for speeds of 400 r.p.m. and above and it has been found that the 11¾-in. rock bit gives the best service with very high rotating speeds. This size is used from the bottom of the surface string to 8200 ft. At this depth the rotating speed has been gradually reduced to 400 r.p.m. and here an 11-in. bit is put on. The same speed of 400 r.p.m. is used but this is later reduced until, with very hard digging, the speed is sometimes as low as 250

r.p.m. No reamers are used but the hole stays out to gauge.

The rate of penetration at the highest rotating speed after setting the surface string averages 40 ft. in 4 minutes. Actually it takes longer to make connections than it does to run down the kelly. Including the time for making connections and all operations, a penetration as high as 1080 ft. has been made in nine hours. The bit being continuously on bottom during this time, the teeth were naturally worn down and caused a lower rate of penetration toward the end of the run.

The very high speeds are maintained to a depth of approximately 5300 ft. after which the formations become harder and the driller begins to reduce the rotating speed. By doing this it has been found that more service can be obtained from the bits. At the casing point, which is slightly below a depth of 11,000 ft. at Rio Bravo, the rotating speed will have been reduced to 250 or 300 r.p.m. and the rate of penetration here is from 8 to 10 ft. per hr.

In one well at Rio Bravo the water string was set at 11,300 ft. This depth hole was drilled with 43 rock bits. As much as 56,000 ft. of hole has been drilled with high-speed rotation with only one bit failure and one drill-pipe failure.

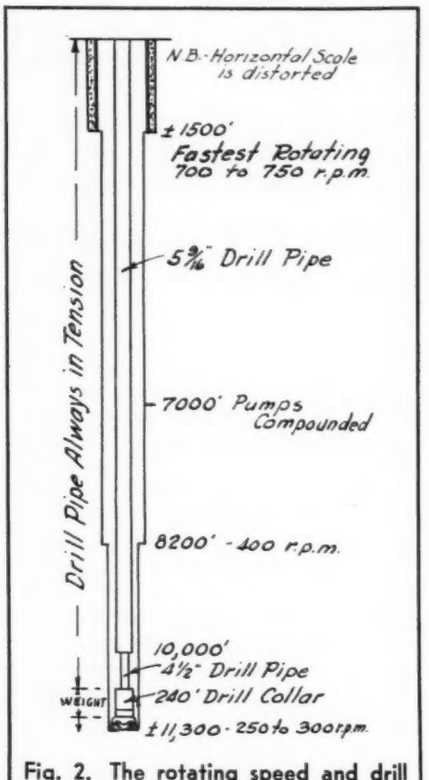


Fig. 2. The rotating speed and drill pipe used to various depths in the Rio Bravo operation are shown in this sketch

Bit performance while drilling straight, fast hole with high rotating speed is, of course, influenced by the drill string and circulation. No drill pipe less than 4½-in. is used with high table speeds and the 5-9/16-in. drill pipe is utilized as much as possible. The practice in the Union wells is to drill with 5-9/16-in. drill pipe to approximately 10,000 ft. Then, instead of laying this pipe down, a 4½-in. stinger is used on the end of the 5-9/16-in. for drilling from 10,000 ft. to the casing point below 11,000 ft. This gives better circulation and eliminates the necessity of laying down the 5-9/16-in. string and running a full string of 4½-in. After the 7-in. casing is set, this combination string must, of course, be laid down and 3½-in. drill pipe used to drill through the sand with a 6⅛-in. bit. In completing the well, a 5-in. liner is set through the oil zone.

Mud fluid is circulated by 15½ by 8½ by 20 pumps. The pump speed is kept under 44 s.p.m. and, while maintaining this speed, the pump discharge valves are throttled gradually until a pressure of 1600 lb. per sq. in. is attained. At a depth of approximately 7000 ft., however, two pumps are compounded. At a pressure of 1600 lb., the circulation through 5-9/16-in. drill pipe is 900 gal. per min. The highest pressure necessary with the 5-9/16-in. drill pipe to 10,000 ft. is 1600 lb. whereas a pressure of approximately 1800 lb. would be required with a full string of 4½-in. pipe. Rubber protectors are used on the drill pipe through the casing, mainly for a stabilizing effect at high-speed rotation.

The drill collars are important factors in drilling with high rotating speeds. The weight carried on the bit is confined entirely to that supplied by the drill collar and the pipe above the collar is kept in tension at all times. In drilling from the top of the hole to the casing point, a 240-ft., 8¼-in. drill collar weighing approximately 18 tons is used. This not only provides the best assurance of keeping the hole straight but reduces wear on the drill pipe and tool joints and keeps down the hazard of twist-offs to a minimum. On the 3½-in. drill pipe, a 4¾-in. drill collar is used while coring and drilling through the sand.

Octagonal kellys are used exclusively for drilling with high-speed rotation on the Union wells. The larger opening through this type kelly is advantageous but the most important feature is the reduction of vibration obtained by using the octagonal design. The vibration on the floor and in the derrick when using high table speed is excessive with square kellys and this is practically eliminated by using the octagonal shape.

An individual engine for driving the rotary machine is necessary for high-speed rotation and a 12 by 12 twin-cylinder steam engine is being used for this purpose. The engine is placed under the derrick floor and is direct connected to an extension shaft by a flexible coupling. The table is chain-driven from a sprocket on the driveshaft, the enclosed chain drive extending upward at an angle from the driveshaft to the table above.

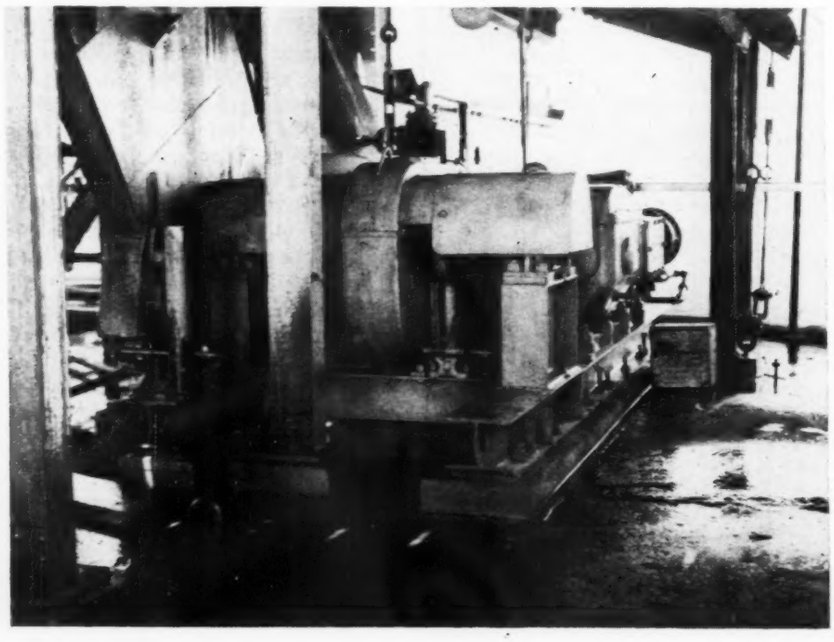


Fig. 3. Rotary table is chain-driven by a 12 by 12 twin-cylinder engine placed below the derrick floor

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The Technology of Refining Processes

Article 3

DEHYDRATION and POLYMERIZATION of LIGHT HYDROCARBONS

By
ARCH L. FOSTER
The Lubri-Zol Corporation, Cleveland, Ohio

ONE of the greatest conservation problems of the petroleum industry has been the utilization of the huge quantities of light hydrocarbons produced as natural and "casinghead" gas, and the similar products formed during refining operations, especially in cracking and reforming. The total amount of these natural hydrocarbons produced in this country alone during recent years approaches astronomical figures. A large part of this production, under our present technical development, can still be used only as fuel "as is", particularly the methane, ethane, and most of the propane available. Technical research has shown how these hydrocarbons, even methane, can be converted pyrolytically to yield a fair percentage of benzene and other aromatic liquid and solid products, but commercially these developments hold no promise as yet, except possibly in small quantities for the preparation of intermediates for the chemical industry. As will be shown later, we have learned how to utilize ethane in the manufacture of super-aviation fuels, but that outlet for ethane is limited at present.

To utilize propane and butanes, however, recent developments have made practical a number of processes that are in the course of revolutionizing our entire hydrocarbon fuel standards and economics. These processes include dehydrogenation and hydrogenation, polymerization, alkylation, and the lesser-known and not yet well-developed reactions, isomerization, aromatization, and cyclization. The guiding principle in all these processes is the rearrangement of molecular structure, and the combination of molecules, themselves not possessing the chemical or the physical properties required by modern industry, into other molecules having those attributes most needed in present-day fuels.

The incentive to technologists to develop means of utilizing these formerly almost waste products is obvious when it is noted that by estimate more than 200,000,000 bbl. of polymerized gasoline may be produced yearly from the propane and butane available in the United States, of which 10 to 12 percent may be aviation fuels of 95-100 octane number. (Egloff et al, A.P.I. Proc. III, 1937). Gard estimates that 2,100,000 bbl. of alkylation products may be obtained annually from the olefins available in California alone, of which 1,800,000 bbl. would be aviation fuel of about 95-96 Army octane number. (Gard et al, Proc. Calif. Nat. Gaso. Assn., Nov. 17, 1939). He estimates also that about three times as much aviation fuel of 100 octane number can be produced by alkylation as by polymerization - hydrogenation methods.

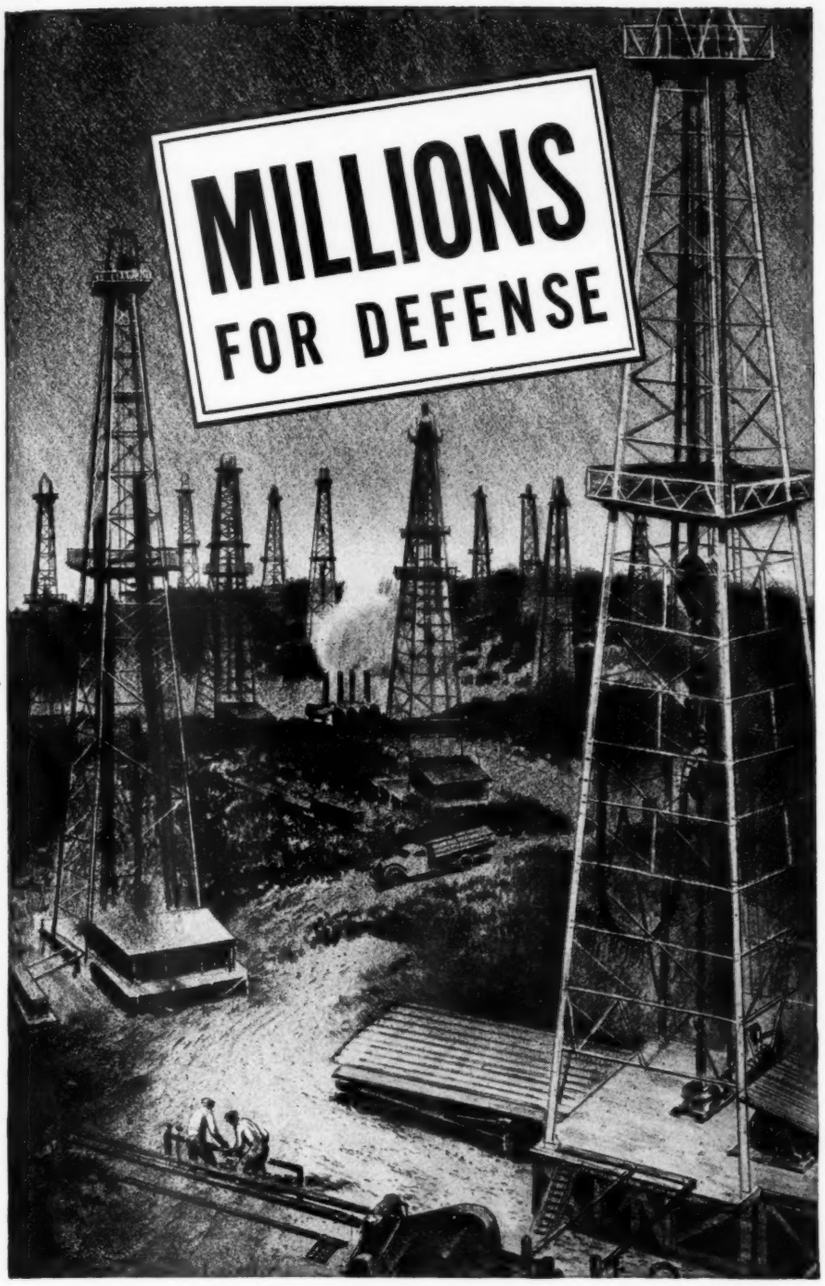
ARCH L. FOSTER

is widely known in refining and automotive technical circles—His present work as sales engineer for The Lubri-Zol Corporation is concerned principally with lubricants and lubricant-treating methods — Previous experience since 1922, when he graduated from the University of Texas, was with the Gulf Refining Company, the U. S. Bureau of Mines, and the *National Petroleum News*.

In either polymerization or alkylation the primary requirement is a supply of olefins. The butenes have been the most used material, but propene is finding wider and wider use as the technology of processes becomes more efficient. Olefins produced in cracking have been and are at present the major source of supply of olefins, and these may be segregated by fractionation or may be carried through the reaction in the presence of paraffins, etc., with which the olefins are mixed in the still gases. In the making of specially pure fuels of high octane number, however, the olefins must be carefully purified at considerable cost, or paraffins must be concentrated and dehydrogenated to form the charge stock for the final operation.

Due to the developments of the last two or three years, the concentration of natural gases from oil- and gas-producing fields offers no serious obstacle, either technically or economically. For example, for several years propane and butanes have been gathered in the East Texas field by an intricate pipe line and gasoline plant system that combines the production of a dozen plants and delivers 3500-5000 bbl. of propane-butane per day to a refinery on the Gulf Coast, along with large amounts of natural gasoline. At present this quantity of gases is doubtless greatly increased over these figures. (*National Petroleum News*, Mar. 23, 1938, p. R-121).

More recently a refrigeration process for recovering light gases has been commercialized. Propane from the overhead stream of a natural-gasoline stabilizer is liquefied by water cooling at 200-lb. pressure, and is used to supercool the compressed natural gas, at 50- to 60-lb. gauge pressure, to as low as minus 35°F. to recover all propanes and heavier. Raw liquid propane and as much of the butanes as may be desired are separated from the natural gasoline. Such a process may be used equally well in any refinery where it is desired to concentrate any fraction of very light products. An important item in the process is the dehydration of the gases before compression and expansion to obtain the extremely low temperatures, thus preventing ice or gas-hydrate formation plugging lines and other equipment. Special dehydrating or drying agents are employed that have proved to be



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highly efficient. *(National Petroleum News*, Sept. 21, 1938, p. R-458).

Dehydrogenation of Hydrocarbons

Two types of dehydrogenation methods are available to the refiner—thermal and catalytic. Thermal processes include the familiar cracking unit, in which olefins are formed as undesirable by-products. Thermal processes are generally considered less efficient than catalytic because of inability to control the process in preventing too much hydrogen removal; thus the yield efficiency of the method is reduced. Good results have been obtained, however, in large-scale practice, one of the most noteworthy examples being the Shamrock Oil and Gas Corporation's plant in the Texas Panhandle. Concentrated butanes from natural and refinery gases are pumped through cracking coils and cracked to butenes, 1000-1150°F. and 800-1000-lb. pressure per sq. in. being required to crack a given percentage of the charge. The uncracked butanes are recovered and recycled. Experience has shown that in any given unit only a portion of the gases—10 to 50 percent or possibly more in certain cases—should be cracked per pass; otherwise too much hydrogen, carbon, and other undesirable decomposition products are formed, reducing yields and increasing costs.

In the new neohexane synthesis, discussed below, ethane is cracked to produce ethylene at 1425° F. but at only "a few pounds above atmospheric" pressure—conditions that are said to give the best yields of the olefin. Here it may be noted that the lower the molecular weight of a hydrocarbon, the higher the temperature required to crack or dehydrogenate it; this holds as a general law throughout the petroleum hydrocarbon range.

The newer catalytic methods for dehydrogenation now hold much greater interest. Two processes were announced during 1938 and 1939. Shell Development Company obtains 72 percent yields of *iso*butene from *iso*butane at 600°C. (1112°F.) and space velocities of 2 to 75 ft. per min. Propane is best converted to propene at 1150-1200°F. The catalyst is a specially prepared aluminum oxide activated by such "promoters" as chromium oxide, iron and zinc oxides, vanadyl sulphate, reduced nickel, etc., the combination resulting in many times the efficiency of the alumina used alone. *(National Petroleum News*, Sept. 7, 1938, p. R-432).

The hydrocarbon to be dehydrogenated, in fairly pure concentration, is dried by passing it through granulated calcium chloride, for example, or other drying agent that does not impart to the gas stream any impurity that will poison the catalyst. It then passes through tubes or chambers containing the catalyst supported on trays or by any other arrangement that gives intimate gas-catalyst contact, the catalyst and gas being maintained at the optimum temperature. Undehydrogenated gas is recovered from the reaction products and recycled.

One peculiar fact has been found regarding the work of the dehydrogenation catalyst, a fact that has also proved to hold for polymerization catalysts. A small amount of water, about 0.1 mol-percent in this case, must be present in the reaction gases, if the catalyst is to be effective. A dry catalyst is a relatively inactive one, and the complete absence of water may in some cases render a catalyst entirely inactive. The Shell process shows that a monomolecular layer of water must be present on the catalyst if it is to reach its highest efficiency. Just what the role of the water is is not entirely certain, but doubtless it fulfills the function of a sort of secondary promoter, in the sense that the Russian-American authority, Ipatieff, uses the term. Hydrogen sulphide may be used in the place of water, as it does not poison the dehydrogenation catalyst.

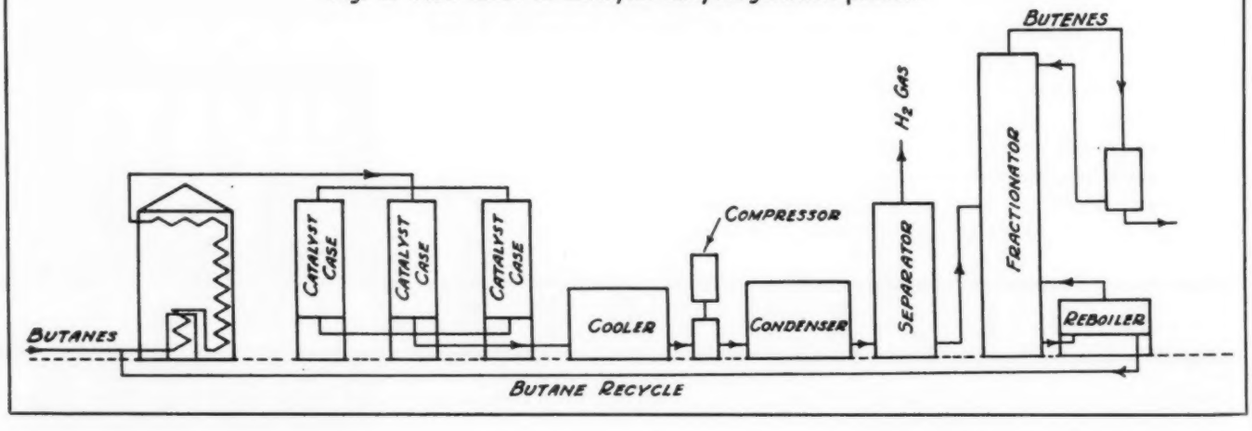
Another interesting fact regarding this process is that, with the catalysts used, space velocities and temperatures are especially important. With optimum temperatures in the range of those mentioned above, it is found that at one as high as 1022°F. very little reaction takes place. Raising the temperature produces lower olefins; with rupture of the carbon-carbon bond, free carbon and hydrogen are formed, reducing the yield of the desired olefin. As space velocities are increased, yields per unit of time are increased, but catalyst activity falls off more rapidly, and periods between regenerations are greatly shortened.

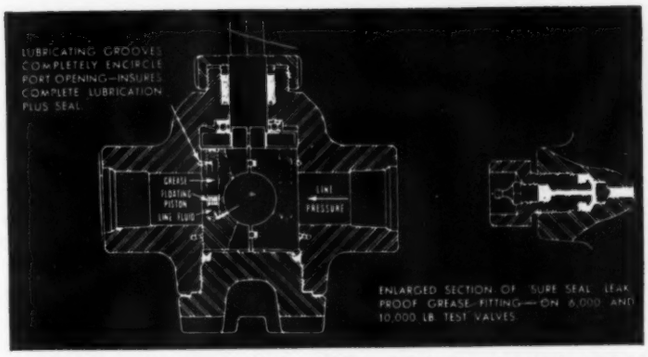
The relative activity of the plain alumina catalyst and the same catalyst activated or promoted by other materials is indicated by the following results: plain alumina converts 31 percent of *iso*butane to *iso*butene in 3 hr.; alumina with 2 percent chromic oxide produces 35.5 percent conversion in 1½ hr., and alumina with 15 percent chromic oxide dehydrogenates 37 percent of *iso*butane in 1 hr. All runs were made at 20 ft. per min. space velocity.

Universal Oil Products Company has developed a dehydrogenation process, also using an alumina-chromic oxide catalyst, from which is obtained yields up to 95 percent of *iso*butene from *iso*butane, and similar yields of olefins from other paraffins such as normal butene from butane. This process operates at low pressures, 15 lb. gauge or thereabouts, at high-space velocities, 500 to 10,000, and at temperatures of 930° to 1380°F. The catalyst is arranged in heat-exchanger-type reactors, which operate on a reaction-

(Continued on Page 42)

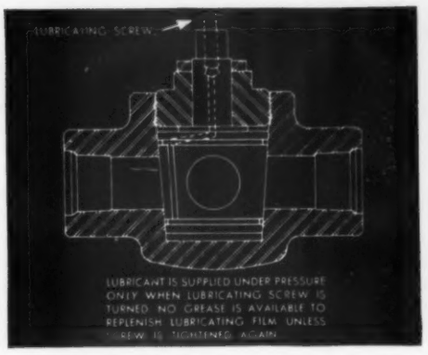
Fig. 1. Flow chart of catalytic dehydrogenation process




LUBRICATING GROOVES COMPLETELY ENCIRCLE PORT OPENING—INSURES COMPLETE LUBRICATION PLUS SEAL
GREASE
FLOATING PISTON
LINE FLUID
LINE PRESSURE
ENLARGED SECTION OF SURE SEAL LEAK PROOF GREASE FITTING—ON 6,000 AND 10,000 LB. TEST VALVES

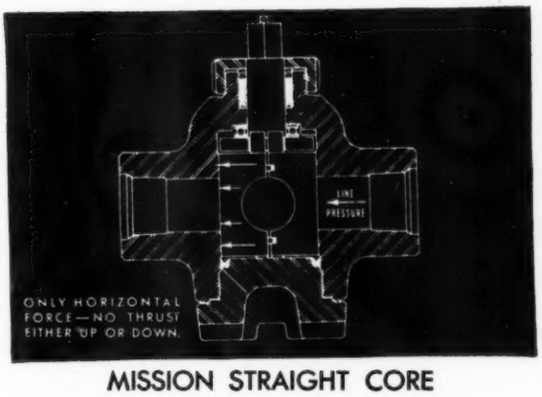
MISSION AUTOMATIC "FULL-PORT" LUBRICATION

Line pressure against piston in lubricating storage reservoir automatically forces and holds sufficient lubricant in place in the grease grooves to both lubricate and form a perfect seal at all times regardless of pressure.


LUBRICATING SCREW
LUBRICANT IS SUPPLIED UNDER PRESSURE ONLY WHEN LUBRICATING SCREW IS TURNED. NO GREASE IS AVAILABLE TO REPLENISH LUBRICATING FILM UNLESS SCREW IS TIGHTENED AGAIN

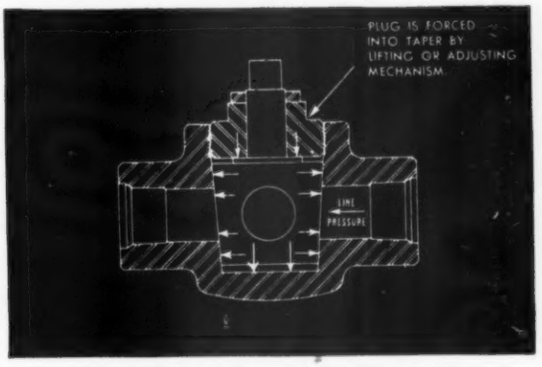
CONVENTIONAL LUBRICATION

Lack of constant pressure to replenish the lubricating film as rapidly as necessary can quickly cause serious damage and leakage.



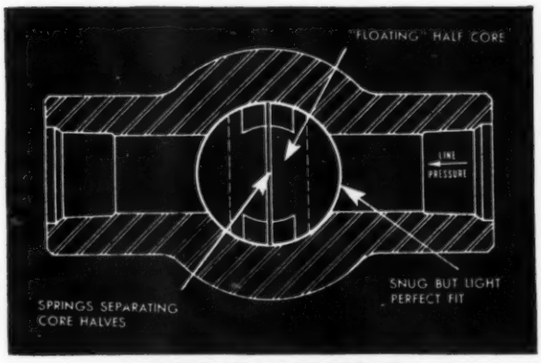
MISSION STRAIGHT CORE

A cylindrical plug seats perfectly and permits minimum side wall clearance. Constant lubricating seal is easily maintained. This increases valve life — assures easy operation.



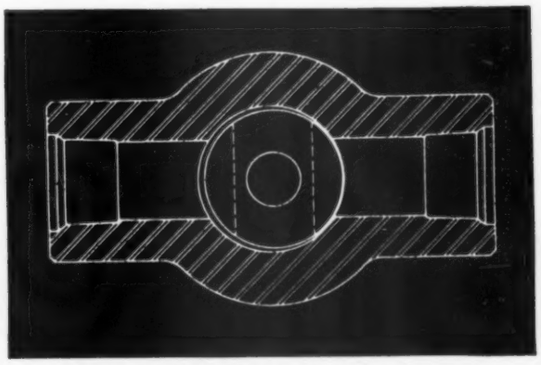
CONVENTIONAL TAPERED PLUG

A tapered plug also has vertical motion. It can seat perfectly only when wedged. Greater side wall clearance in operation makes a perfect seal difficult and allows opportunity for sand to accumulate under the seat. This increases friction and wear.



MISSION SPLIT CORE

Perfect contact with body allows instant seal under pressure. This protects surfaces from sand and grit, reduces cutting and wear, and reduces maintenance costs.



CONVENTIONAL SOLID PLUG

Unless wedged, a solid plug cannot fit its seat perfectly. As the plug wears, it cannot fit. This permits accumulation of sand and grit, accelerating wear, and greatly increases difficulty of operation.

Mission Plug Valves are made with the same careful standards of metallurgical research, manufacturing precision and inspection that have made each Mission product a leader in its field. This valve again emphasizes our long-established policy, "If a product designed by Mission is not proven superior, Mission will not produce it."

Mission Plug Valves are manufactured in 2″, 3″ and 4″ sizes and in three grades—4,000, 6,000 and 10,000 lb. test pressures—and are available or can be ordered from leading oil well supply warehouses. Prices of each style and size compare favorably with those of the best plug valves formerly available. Full details are available on pages 1716 to 1724 of The Oil Weekly Composite Catalog of 1940.

Install Mission Plug Valves under your most difficult operating conditions. They will save you time, labor and money.

MISSION MANUFACTURING CO. • HOUSTON, TEXAS

(Continued from Page 38)
regeneration cycle of about one hour, the fouling carbon on the catalyst being burned off by heater air much as it is in the Houdry catalytic cracking process. Here the catalyst is not poisoned by sulphur nor by carbon monoxide but deposition of iron oxide must be avoided. (E. Houdry et al, A.P.I., Nov. 17, 1939). The liquid and gaseous hydrocarbons from the reactors are divided into three parts, the lightest being essentially hydrogen, which may be used to hydrogenate olefin polymers; the unconverted paraffins, which are recycled to the unit, and the olefins, which are stored to be used for whatever purpose they may be intended, polymerization or alkylation. This produces a continuous and essentially self-sufficient unit, since the butenes, for example, may be polymerized to *iso*-octene, which can be hydrogenated catalytically to *iso*octane, using the hydrogen removed from the paraffins in the first step.

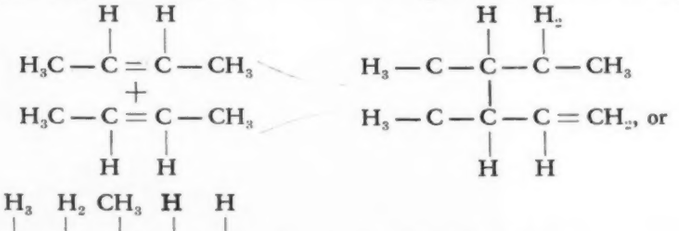
The catalyst used in this process is said to be very rugged and to maintain its selectivity and activity with only slight decrease over periods longer than 2000 hours. Three commercial units were under construction late in 1939 to process a daily total of 3000 bbl. of butane, which will be polymerized and hydrogenated to *iso*octane, yielding more than 2000 bbl. per day of this most important blending material for aviation and motor fuels.

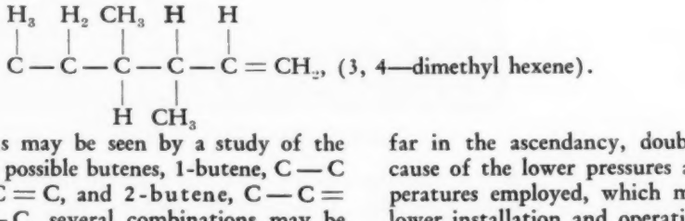
Polymerization

Probably no single development in recent years has done so much to enable the refiner to keep pace in the "octane race" as has the polymerization process, made commercial in the early thirties. Adding 3 to 8 percent or more to the total yield of gasoline from the crude run, polymerized gasoline shows 78-82 octane number with a "blending octane value" of 85-100 or more. With such a blending fluid, the refiner, especially the smaller company with limited technical staff and financial resources, has been able to meet competition in anti-knock rating with far less expenditure for tetraethyl lead. In so doing the large and small refiner alike have been able to cope with the crushing effect of unbridled price competition on the one hand, and of mounting quality and therefore mounting manufacturing costs on the other. Various calculations indicate that polymerized gasoline having as high as 85 octane number or thereabouts is valued at one to two cents and more above the price of regular housebrand gasoline, at the refinery. In addition the daily bill for crude oil is reduced appreciably. Atlantic Refining Company's thermal unit discussed later herein enabled that company to save an estimated 3000 bbl. of crude oil per day in producing the same volume of motor fuel, at a "laid-down" cost approaching $5000 per day at the refinery.

Individual small refiners have valued polymer gasoline produced catalytically at prices as high as 10 cents per gal., based on their individual positions, crudes, and the cost of buying lead, benzol, or other blending agent to produce a competitive gasoline. The cost of lead required to raise the rating of a gasoline one octane number varies widely with the range of knock rating involved and the lead susceptibility of the gasoline treated, but a typical cost in the 65-75 octane number range may be taken as 0.06 cent per octane number. On that basis, a blending agent that, unit volume for unit volume, will raise the anti-knock rating of a gasoline by 10 numbers may be valued at 0.60 cent premium over the price of "regular" motor fuel.

Polymerization reactions involve simply the combination of two or more molecules to form one larger molecule of the same general type or structure. In practice polymerization in the refining industry is the reaction that adds together olefin molecules by the breakage of one linkage of a double bond in each and by combination of the carbon chains. These polymerization reactions may take place in a number of ways, one of the common ones being as follows, starting with 2-butene:





As may be seen by a study of the two possible butenes, 1-butene, C—C—C=C, and 2-butene, C—C=C—C, several combinations may be formed by them during polymerization, by reacting the same butene with itself and with its isomer, and by forming the polymerizing bond between different carbons of the C=C complex. The resulting molecule is still an olefin, which possesses lower vapor pressure and higher octane number than the original reactants or the corresponding normal paraffin isomers, and which may be used as such or may be hydrogenated as in the example given above to *iso*octane or other *iso*-paraffins.

By polymerizing propene with butenes and with pentenes or ethylene, a more complicated mixture of higher olefins is produced, forming unsaturated fuels with octane numbers of 80 and higher. Each olefin reacts best at a different temperature, so that much of the operation in present-day polymerization plants, if intentions are to produce a specified high-quality motor-fuel blending agent, is of the selective type—concentrating a single olefin by fractionation and polymerizing it under optimum conditions for that olefin. For most refiners the non-selective type of plant is more economical and more profitable, giving higher total yields because all olefins in the charge stock may be brought into reaction even though the percentage of any individual olefin polymerized may be lower than would be the case if operating on that olefin alone. In selective polymerization, conditions are chosen that are optimum for that particular charge stock rather than a compromise set of conditions such as would be used in the case of mixed olefins.

The exact number of polymerization plants in the United States is not known to the writer, but the value of the process to the refiner is indicated by recent reports that 31 units were built or under construction during 1939, most of them being of the catalytic type.

Both thermal and catalytic units are in operation, with the catalytic unit far in the ascendancy, doubtless because of the lower pressures and temperatures employed, which makes for lower installation and operating costs. The first "poly" units to be built by American refiners were those designed and built by Pure Oil Company to polymerize by thermal methods the olefins from high-temperature vapor-phase cracking. These units operated at several hundred pounds pressure and at temperatures of 1000° F. and higher. The still gases were led into a heating coil and brought to reaction temperature, passing through reaction coils in which, in later designs, colder gases

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S 3902

FIELD: Rosenberg
TYPE OF JOB: Casing (drill pipe cemented in hole)
DEPTH OF WELL: 7,743 ft.
MAX. TEMP.: 180° F.
SLURRY WEIGHT: 16.5 lb. per gal.
CEMENT USED: 'Starcor', 570 sacks
PUMPING-DOWN TIME: 35 min.
MAX. PUMP. PRESSURE: 1500 lb.
REMARKS: When they topped the sand, well blew out around surface pipe. Mud-weight was then raised from 10.5 lb. per gal. to 14 lb., and surface-casing re-cemented. Then they found the drill-pipe was stuck; instead of trying to pull it or cut it from hole, they cemented pipe in the hole with 'Starcor'.

W 1419

FIELD: Jefferson Texas
TYPE OF JOB: Retainer squeeze
DEPTH OF WELL: 6100 ft.
MAX. TEMP.: 196° F.
SLURRY WEIGHT: 16.4 lb. per gal.
CEMENT USED: 'Starcor', 36 sacks
REMARKS: 20 sacks 'Starcor' pumped into formation with maximum pressure 3800 lb. Well had been making 210 bbl. fluid -- only 10 bbl. oil. After squeezing, well made 252 bbl. oil on ¼ in. choke, with 0.3% water.

IN 'Starcor' we offer you an Oil Man's cement, made to measure for oil-field requirements—not last year's requirements, or last month's, but *today's.* Greater length and ease of pumpability built into the cement by persistent product research, based on continuing study of problems at the rig.

Use 'Starcor' for deep wells—greater length and ease of pumpability at high temperatures, extra sulphate resistance . . . Use 'Incor' for wells of moderate depth —earlier drill out, wells on production quicker. Insist on 'Starcor'* or 'Incor'*—it'll pay you well.

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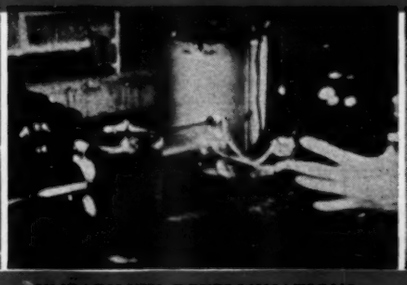
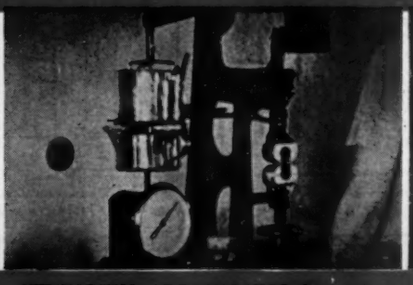
...UING RESEARCH, in laboratory and field enables Lone Star to keep ... abreast of changing oil-field ... ...



PUMPABILITY DETERMINATIONS are daily routine—part of rigidly maintained quality control.



STRENGTHS ARE CHECKED by testing briquettes and cubes, made with different water contents, after 12 hours to 28 days' storage, at 140, 170, 200° F.

HEAVY SLURRIES, with greater length and ease of pumpability—better field results, based on constant research.

were introduced at various points in this coil to reduce the temperature produced by the exothermic reaction. If the temperature is permitted to reach a critical level the reaction may become so violent as to reach explosive proportions. Yields under the Pure process varied widely, of course, depending on the composition of the charge gases, 3 to 7 percent being the approximate range. It is practicable to vary conditions in this process, as is probably done in the other thermal methods, so that the composition of the product may be varied widely. A large proportion of aromatics, including benzene, toluene, xylene, and homologues, can be produced at high temperatures and relatively low pressures. Because of the variety of products that can be produced, this process has been used in at least one or two plants primarily for the production of olefins, aromatics, and other hydrocarbons for use as chemical intermediates. A number of widely used industrial chemicals are now made from polymerized products by employing this process.

A more recent thermal process, the Polyco, has proved successful in a number of installations as typified by the Atlantic Refining Company unit built some three years ago. Processing 22,000,000 cu. ft. of refinery still gases per day, this unit produced 1850 bbl. of polymer gasoline per day, and reduced the daily crude requirements of that 90,000-bbl. refinery by about 3000 to 3500 bbl., a saving of nearly $5000 per day. The polymer gasoline produced showed 76 octane number, with 84 octane blending value. The feed gases were composed of still, storage tank, and other plant gases, along with gases relatively rich in C_3's and C_4's from the stabilizer overhead stream.

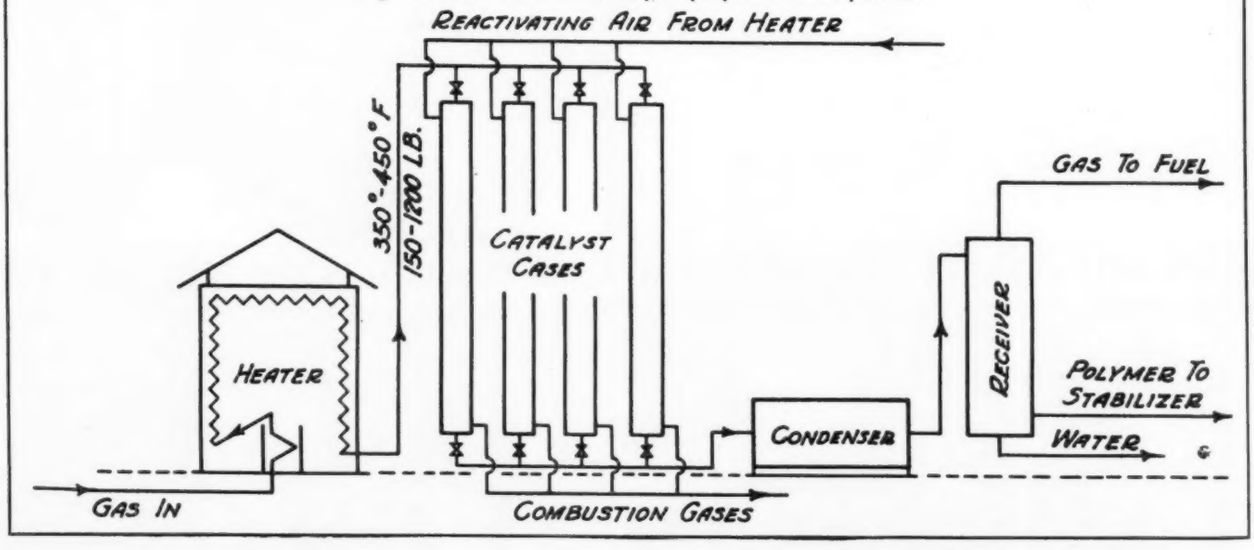
These gases were stripped of 95 percent of their sulphur in a Koppers phenolate unit, and the heavier hydrocarbons concentrated by absorption and rectification to recover light gasoline fractions as tower bottoms and polymerizer plant charge as an overhead product. This charge is preheated, in this case in parallel streams in the transfer line heat exchangers that were installed to recirculate 58,000,000 B.t.u. per hr. of the excess heat in the reacted gases passing to the fractionating tower. The preheated gases, in this instance at 730° F., and 1800 lb., pass through the heater coil and out at 1000°-1030° F., to exchange heat with the incoming charge as outlined above, and to the fractionator. Although not an essential part of the process, technically speaking, an interesting method of utilizing otherwise waste power is used in this unit. High-pressure gas from the vapor recovery system at pressures from 200 to nearly 400 lb. is expanded in engines as steam would be used, and thereby nearly 1000 hp. is recovered that would be wasted without this adaptation.

This unit recovers about 3.5 gal. of polymer per 1000 cu. ft. of gas processed, which amounts to more than 68 percent weight yield on the C_3's and C_4's present. About 10 percent conversion (polymerization) per pass is found to be optimum for this type of operation. Higher conversion rates produce side reactions, tripolymers and other undesired products, such as tar, which foul the unit, cause more frequent cleanouts, and reduce yields. Thermal polymerization leaves something to be desired, in that reactions cannot be controlled with needed exactness, and therefore side reactions must be reduced to a minimum by careful control of conditions. To prevent deposition of tars and coke, the gases through the high-temperature exchanger travel at a rate of 150 mi. per hr., which at 1800-lb. pressure gives a strong sweeping action to keep the tubes clean.

Catalytic Polymerization

Because of lower temperatures and pressures and consequent lower installation and operating costs, the use of catalysis for polymerizing gases has progressed more rapidly than thermal methods. The best-known process is that developed by Universal Oil Products Company using a "solid phosphoric acid catalyst," that is, an inert material impregnated by phosphoric acid or its salts, placed on trays or filled into vertical cylinders, the form of the particles being such that adequate open space is left for the passage of liquids or vapors. Light refinery vapors, preferably cracking still gases containing a large percentage of butenes, are compressed to 200 lb. or more, passed through heating coils to be heated to 400° F. or lower temperatures, and are contacted by the catalyst in a series of these vertical towers of which two or more may be used at once, with at least one being regenerated at any given time. The reaction is strongly exothermic, so that gases entering the towers at 400° F. may reach 500-550° F. at the exit. The gases from the reactors are fractionated to recover the polymer and the unreacted portion may be recycled, either to convert the remaining olefins or to dilute incoming gases that may be too rich in olefins for

Fig. 2. Flow chart of catalytic polymerization process



the best results. Optimum conversion rates are obtained with gases having 25-30 percent olefins; as cracked gases frequently contain 40-50 percent olefins, the tail gases, which in a well-operated plant have very little olefin left unpolymerized, are returned in the necessary proportions to the intake gas to maintain the desired optimum concentration of olefins in the charge entering the reacting towers.

Earlier units were operated at 200-400-lb. pressures. It was found, however, that higher pressures give better yields with less refining loss and smaller percentages of by-products. Units are now reported to be operating at 1000-lb. pressure or higher, with the result that the charge is liquefied before reaching the reactors. One theory is that the liquid charge "washes" from the catalyst reacted materials, which, if allowed to remain in contact therewith too long, would be overpolymerized, resulting in production of heavy gums, tarry material, and other products that reduce yields, increase the undesirable properties of the product, and decrease the length of time between regenerations.

The average polymerizer unit yields 3 to 5 percent polymer gasoline, in terms of the charge to the cracking still. The product is composed chiefly of olefins with a boiling range to 400° F.; the initial boiling point may be controlled at whatever temperature the operator chooses, by retention or rejection of butane from the charge gases, in the final product. The octane rating may be 80-85 A.S.T.M., with a blending value of 100 or more, depending on the rating and properties of the refinery gasoline with which it is blended.

Care must be observed in operating these units to prevent the temperature from mounting too high because of the exothermic reaction. Too high a temperature results in a quickly carbonized catalyst, and necessity for frequent regenerations and loss of efficiency for the entire unit. Thirty to fifty gal. of polymer may be produced per lb. of catalyst between regenerations.

As referred to earlier, in using dehydrogenation catalysts, a small amount of water is necessary to make the catalyst efficient, usually 0.1 mol-percent to 0.2 mol-percent being added to the entering gases by means of a proportioning pump. Catalyst is regenerated at intervals of 500 to 1000 hr., when its efficiency has fallen to 75 percent or lower. Carbon deposited on it is burned off by the introduction of heated air; the towers are usually in parallel so that one or more towers may be bypassed at any time for regeneration. The catalyst may be regenerated at temperatures as high as 950°F. without damage to its efficiency. (*National Petroleum News*, Aug. 25, 1937, p. R-129; Aug. 10, 1938, p. R-371).

Earlier catalyst units were built by Universal Oil Products Company, only in larger capacities. The largest unit of which we have definite knowledge in the United States has a capacity of 27,000,000 cu. ft. per day. In 1938 several so-called "midget" units were built, some of them operating on less than 200,000 cu. ft. of gas daily, with such signal results that the application of this process to refineries having 1,000,000 cu. ft. or less of available gas has increased rapidly all over the country. In 1938 it was estimated that 135 refineries, not formerly considered large enough to warrant operation of a catalytic "poly" unit, were a potential and practical field for this process. Since that time a large percentage of this number has been built.

The Houdry Process

The Houdry Process Corporation has developed a liquid-phase, polymerization process employing a catalyst presumably of aluminum hydrosilicate composition. Yields of polymer gasoline of 85 octane number, a blending value as high as 130 or higher according to published figures are obtained with conversions as high as 55-70 percent by weight of unsaturates per pass. With a selected charge stock this product is reported to be a good base material for hydrogenation to *iso*octane and other high octane number aviation fuels. Little has been disclosed publicly of the details of this operation. Estimates of $32,000 cost for a plant processing 2000 bbl. per day of liquid butane-butenes have been made, or double this amount if fractionating equipment is added. Like all the Houdry processes, regeneration of the catalyst is required, cycles of 6 to 12 hours being employed in polymerization operations. This process appears to offer good possibilities for the production of both motor and aviation fuels, through the polymerization-hydrogenation route, as do other polymerization methods when combined with hydrogenation.

Space does not permit more detailed discussion of the problems encountered in polymerization, nor of the economic and technical advantages and disadvantages of these processes. This development has enabled the refiner, especially the small refiner with limited capacity, to compete on more nearly even terms in supplying motor fuels having adequate octane ratings. It has fostered improvement of aviation fuel anti-knock ratings, and was the first step in the production of technical *iso*octane and attainment of a 100 octane number as a commercial practicability in large quantities, combined with hydrogenation of the olefins so polymerized.

AUTHOR'S NOTE: The fourth article in this series will discuss alkylation, hydrogenation, and other reactions involving the synthesis and rearrangement of light hydrocarbons. Polymerization, which has been employed successfully in the synthesis of heavy hydrocarbons, such as lubricating oils by the action of aluminum chloride on heavy olefins through the Friedel and Crafts reaction, has been omitted from this article because of lesser practical interest at present, but will be discussed briefly in a later article.

Tabulated Analyses of Texas Crude Oils Available

INFORMATION regarding the analyses and other characteristics of nearly 500 crude oils from various Texas fields is given in a report published by the U. S. Bureau of Mines.

The State of Texas has been credited with more than half of the proved oil reserves of the United States and currently is producing approximately 40 percent of the total output of petroleum in the United States from a very large number of oil fields.

The Bureau of Mines has collected samples from individual wells in many of these fields as well as composite samples representing 2 to 100 wells in some fields. The total number of such samples is 479; these analyses are tabulated in summary form in the paper, giving data on sources of samples and characteristics of the crude oils, and on the distillates obtained from the samples by the Bureau of Mines Hempel analysis.

This report, entitled Technical Paper 607, "Tabulated Analyses of Texas Crude Oils," by A. J. Kraemer, Gustav Wade, and E. L. Garton, may be obtained from the Superintendent of Documents, Government Printing Office, Washington, D. C., at a price of 15 cents per copy.

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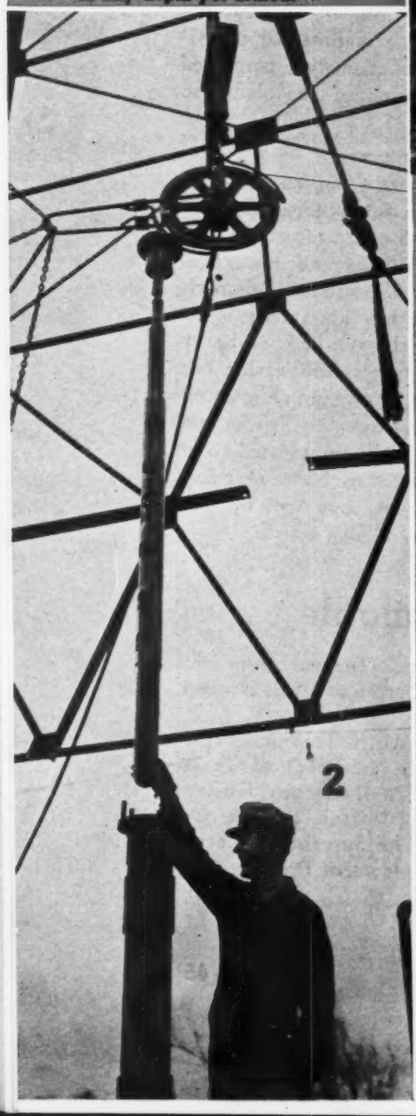
12,000 to 16,000 feet of steel-shrouded cable is measured accurately over the suspended sheave to lower the gun to any depth yet drilled.



2

Lane-Wells pressure packing gland makes possible safe gun perforation of wells having pressures in excess of 2000 pounds per square inch above the hydrostatic pressure.

3

Powder is accurately measured and loaded to assure uniformity of charge for each shot. Each cartridge is tested electrically for continuity of circuit.

4

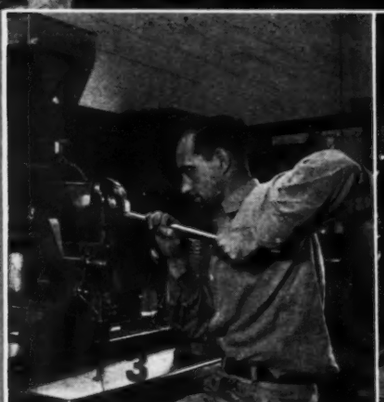
Each chamber passes many inspection tests before it is released for use. In the field constant checks maintain equipment to Lane-Wells high standards.

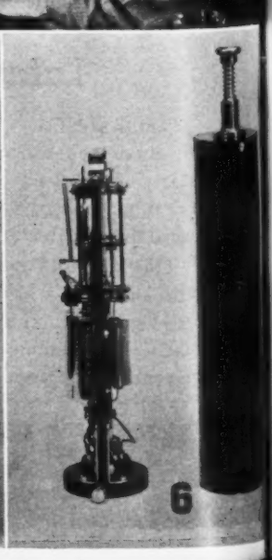
5

Each chamber is tested electrically at the rig before being loaded in the gun. Every possible precaution is used to assure efficient gun action in the hole.

6

The control head of Lane-Wells gun perforator makes possible individual discharge of shots and prevents multiple discharge which might damage casing.





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Deepening and Completing a Well in the Lisbon Field, Louisiana—A Study in Modern Coöperative Practice

A PETROLEUM ENGINEER FEATURE

Part 2

By PAUL D. TORREY, Geologist, The Sloan and Zook Company
and
FRANK H. MILLER, Petroleum Engineer
Lisbon Exploration Company, Inc.

GEOLOGY—(Continued)

POROSITY and permeability tests on core samples from the First and Second sands were graphically plotted. The average porosity of the First Sand is 10.5 percent and its average volumetric capacity is 815 bbl. per acre-ft. The permeability of the First Sand varies from 0 to 4750 millidarcies, according to the analyses of two different companies. The very high permeability of certain parts of this sand is unusual for the sands of the Cotton Valley formation.

The average porosity of the Second Sand is 9.5 percent and its average volumetric capacity is 737 bbl. per acre-ft. The permeability of the Second Sand varies from 0 to 140 millidarcies. The low permeability of the Second Sand will retard the production of gas from it.

Both the porosity and permeability of the Vaughn sand must be quite high as it was brought into production, after the casing was perforated, without swabbing.

Owing to the high temperatures encountered in the lower part of the Vaughn well, it was quite difficult to detect appreciable quantities of gas or light oil from a superficial examination of core samples.

f. Lower Marine sands of the Sugar Creek field. The electrical log of the Brownfield well (Fig. 1) indicates low porosity and permeability in the Lower Marine sands. Cores of these sands indicated that they are gas-bearing. The porosity of the sand in Unit No. 2, Table 8 varied from 2 to 9 percent, and the permeability was almost zero. The porosity of Unit No. 6, Table 8 varied from 2 to 16 percent, with only a few beds having a porosity of more than 10 percent. The permeabilities were, for the most part, less than 1 millidarcy. From the physical analyses of these sands it appears somewhat doubtful whether they will produce gas in commercial quantities.

g. Correlation of Lower Marine sands in the Lisbon field with producing horizons of the Cotton Valley field. There has been considerable speculation as to the correlation of the Lower Marine sands encountered in the Vaughn well with the Lower Marine sands of the Cotton Valley field. It is believed that no definite correlation can be made at this time, and it was for this reason that new names were selected for the Lisbon sands. The most that can be stated at this time with any degree of assurance is that the sands in the Cotton Valley field and at Lisbon occupy the same general position in the Cotton Valley formation. No more exact correlation can be made until additional well records are available in the intervening distance between the two areas.

Photographs and biographical sketches of the writers of this article can be found on page 155 of the February issue of *The Petroleum Engineer*, in connection with Part 1.

5. Productive possibilities and possible distribution of the sands of the Cotton Valley formation in the Lisbon area. It is considered quite likely that the First Sand might produce gas and/or distillate at a higher structural point in the area provided definite closure exists in the structure of the Cotton Valley formation. The exceptionally high permeabilities of some of the beds of this sand should result in wells of large size if it is found to be oil- or gas-bearing in other parts of the area.

The Roberta Vaughn No. 1 well appears to be located very near to the boundary separating gas/distillate production and oil production in the Vaughn sand. Oil production may be anticipated from this horizon at lower structural levels, and more truly gas/distillate production at higher structural levels.

The production tests on the Second and Third sands were disappointing due both to low permeability, and to mechanical difficulties encountered during the course of testing and completing the Vaughn well. These sands should not be overlooked in any future deep drilling in the Lisbon field. A moderate increase in permeability should make them important potential producers.

It should also be pointed out that a thickening of the various sand bodies south and southwestward from the Vaughn well may be expected, and in addition it appears quite plausible that some of the sand members encountered in the Brownfield well will lens-out to the north and northeast. Under such conditions, should adequate porosity and permeability be developed in these beds, they might serve as oil and gas reservoirs. The fact that water was found in the First Sand in the Vaughn well has no particular bearing on the productive possibilities of other Lower Marine sands. It is a well-established fact in the Cotton Valley field that the water level in the various productive sands has no direct relationship.

Attention should be called to the possibility that other sand bodies may occur in the Cotton Valley formation below the Third Sand. The record of the Brownfield well indicates a sand section extending for at least 50 ft. below the Third Sand. The record of the Vaughn well at the total depth of 8900 ft.

DRILLING

The drilling of the Roberta Vaughn No. 1, insofar as this report is concerned, relates specifically to the deepening of the hole from a depth of 5313 ft. to the total depth of 8900 ft. Previously, 841 ft. of 9⅝-in., 36-lb. surface casing had been set and cemented with 350 sacks, and 5291 ft.

of 7-in., 24-lb. production casing had been set and cemented with 250 sacks.

The total depth of the well was checked by drill-pipe measurements before any drilling was done, and measured 5313.62 ft. from the top of the kelly bushing. This check of depth measurement was very satisfactory.

The deepening of the well was begun at 4:20 P.M., August 19, 1939, and the total depth of 8900 ft. was reached at 5:15 P.M., October 30, 1939, a total elapsed time of 73 days.

1. Conditioning of hole before the beginning of drilling. Records of verticality tests were checked before drilling was begun, and it was found that the hole was very straight, the maximum deviation from the vertical being less than 2 deg.

Inasmuch as only 250 sacks of cement had been used to cement the 7-in. casing it was deemed advisable to recement the pipe in order to eliminate vibration. Although it was calculated that the cement slurry should have come to a depth of about 3000 ft., as a matter of precaution the casing was first perforated with 5 bullets at a depth of 4000 ft. Mud circulation was immediately established, indicating the presence of enlarged sections of the hole that did not permit the cement to come up to the calculated point. Following this, 250 sacks of cement were mixed and pumped through the perforations at 4000 ft., and the well then shut-down for a period of 72 hr. to permit the cement to set.

Drilling was begun on the afternoon of August 19, and 31 ft. of hole was made. Serious vibration developed both in the 7-in. and 9⅝-in. pipe, and it was immediately concluded that the casing would have to be recemented at upper levels before drilling could be continued with any degree of safety.

The 7-in. casing was therefore perforated with 3 bullets at a depth of 2000 ft.; an attempt to establish mud circulation through the perforations and up the outside of the casing was not successful. Consequently, it was planned to squeeze a few sacks of cement slurry through the perforations to close them, and then to perforate the pipe at a higher level. Shortly after the pumping of the slurry was begun, however, mud returns appeared in the return flow line, indicating that there had been an unequal distribution of the cement on the outside of the 7-in. pipe. Altering the program, 200 sacks of quick-setting cement were then mixed and pumped through the perforations without the appearance of any cement slurry in the return flow line.

From the lack of return of cement slurry it was apparent that the 7-in. casing had not been completely cemented, so on the following day the pipe was perforated with 6 bullets at a depth of 410 ft., these perforations being intended to penetrate both the 7-in. and the 9⅝-in. casing. The 7-in. casing cracked and parted at the point of perforation; 13 joints and an 8-ft. nipple were pulled from the hole. A fishing spear was run-in on the drill pipe to back-off the broken joint. The spear was engaged successfully in the casing, and the coupling on the bottom of the third joint below the parted joint gave way. This pipe was then pulled from the hole.

Eighteen joints of new 7-in. casing with a slip-type joint on the bottom, having a total length of 544.15 ft., and with the bottom joint previously perforated, were then run into the hole, and a good connection made with the casing in the hole. A total of 170 sacks of cement was mixed and pumped through the perforations. This was sufficient cement to bring cement slurry returns from between the 7-in. and the 9⅝-in. casing, but no returns were obtained from the outside of the 9⅝-in. string. Failure of the cement to return on the outside of the surface pipe was attributed to the presence of very porous water sands occurring at shallow depths, which evidently were absorbing large quantities of the cement. To provide additional protection against vibration, steel braces were set between the 9⅝-in. casing and the wall of the cellar, and then cement slurry was poured in the space outside the 9⅝-in. pipe until no more cement could be introduced; afterwards the cellar was filled with cement for a distance of 1 ft. The well was then shut-down for 60 hr. waiting on the cement to set.

After several days, when drilling had been resumed, some vibration was still evident. This was finally eliminated in a successful manner by the welding of 3-in. pipe in a radial fashion from the 7-in. casing, which by that time was securely cemented on the inside of the 9⅝-in. pipe. The radial "spokes" were welded to the steel piers of the substructure situated directly below the rotary table.

The foregoing experience indicates that it is essential in the deepening of wells in the Lisbon field to recement the production string and the surface casing from bottom to top in order to eliminate vibration while drilling. If vibration is permitted to continue, crystallization of the pipe undoubtedly will result that might subsequently produce a fracturing and parting of the casing. It is also apparent that cavities exist in the hole that will require much more than the calculated amount of cement to fill the annular space between the production string and the wall of the hole to the desired level. A total of 620 sacks of cement was required to recement the production string and the surface casing, and it is therefore recommended that a minimum of 600 sacks of cement be available in order to permit the recementation of the pipe in one operation.

It is suggested that after the point of free mud circulation around the production string of casing has been established, through the perforations, that some proportionate idea of the amount of cement that may be required can be established. The first half of the cement mixed should be regular portland cement, and the second half mixed can be a quick-setting grade. This should allow for the drilling of the plug within a period of from 48 to 60 hr. after the casing has been cemented, thereby providing an important saving of time. The compressive strength of the quick-setting grade of cement, pumped around the lower section of the casing, is ample to permit the drilling of the plug with safety in 48 hr. after the cement has been mixed, and were it not for the possibility of encountering some unforeseen difficulty, it is believed that this grade of cement might be used entirely.

Had these conditions and troublesome events been known in advance, a total of five days of time and two extra perforating jobs could have been saved by the complete cementation of the pipe in one operation. This time, of course, includes the time involved in disconnecting the lower part of the parted joint, and the running-in and connecting-on of new casing. Furthermore, the hazards of cracking and parting of the casing by successive perforations will be materially reduced, if the recementation of the pipe can be done in a single job.

2. Equipment used. A picture of the rig and other equipment employed in the deepening of Roberta Vaughn No. 1 is shown in Fig. 3. A brief description of the rig and equipment is here given.

Three 125-hp. boilers were used, with two 10 by 4½ by 10 boiler-feed pumps set directly in front of the fire boxes. An average steam pressure of 300 lb. per sq. in. was maintained on the boilers, and natural gas was used for fuel. An automatic control of fuel consumption, proportionate to the power requirements of the steam engine connected to the drawworks and of the mud pumps, was maintained throughout the entire drilling operation. The boiler intake water was preheated by the exhaust steam from the

boiler-feed pumps and the mud pumps. An intake water temperature of about 150°F. was maintained. Owing to the good quality of the water available, no serious trouble was experienced from the formation of boiler scale. It is estimated that each boiler, during active operation, required 250 bbl. of water per day. The average daily gas consumption for each boiler, when in full operation, was about 200,000 cu. ft. per day.

Two mud pumps were used. One pump had a mud piston diameter of 6¼ in., and the other pump had a mud piston diameter of 7¼ in. The steam piston diameter of both pumps was 14 in., and the stroke of each pump was about 14 in. Each pump had twin reciprocating discharge cylinders. With 300-lb. steam available the stalling pressure of the 6¼-in. pump was about 1400 lb. per sq. in., and the stalling pressure of the 7¼-in. pump was about 1200 lb. per sq. in. The packing of the pumps was maintained in as good condition as circumstances would permit, and a fluid displacement capacity of as high as 23.6 cu. ft. per min. could be maintained by the 6¼-in. pump with a pumping speed of 25 s.p.m.

The mud return flow line was welded into a hole cut in a nipple of 7-in. casing that was set directly above the blowout preventer. The return flow line was about 100 ft. long and ended at a flow box that in turn was attached to the highest end of a steam-driven shale shaker. The mud, flowing through the screens of the shaker, dropped into a small accumulating pit directly beneath, and then flowed into a settling pit. From the settling pit the mud flowed into the main accumulating pit from which point it was picked up by the intake lines to the pumps.

A 122 ft. angle-shape, steel derrick having a base 24 ft. square was used. The derrick was set on a 10-ft. substructure.

A 12 by 12 twin-cylinder steam engine was used. This was connected by chain drive to a four-speed drawworks, which was equipped with a cut-tooth sprocket that connected direct to the rotary table by a protected, oil-spray-lubricated chain. A hydraulic brake was installed when the well reached a depth of about 7000 ft., which materially assisted in the running of the drill pipe into the hole. With this mechanical hook-up, and using 6 lines, the average hoisting speed of drill pipe, when the total depth of the well was reached, was about 80 ft. per min.

A 3-ft., ball-bearing, rotary table with a 1-ft. kelly bushing was used. Feed control was entirely manual.

The traveling block and crown block were equipped with 42-in. sheaves. A 150-ton swivel and a 300-ton hook were used. Two-part drill-pipe slips with knurled dies for friction holds proved to be very satisfactory. A 4-in. kelly having a total length of about 38 ft. was used.

Three and one-half in. drill pipe with A.P.I. regular tool joints having an outside diameter of 4¼ in. and a bore diameter of 1½ in. was used. Subs had to be added to a few joints originally machined with Acme type box and pin.

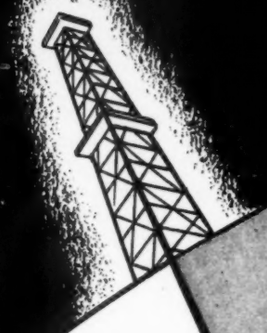
The inside diameter of the 7-in. casing set in the Vaughn well is 6.336 in. No difficulty was met in running 6¼-in. bits through pipe of this diameter. A suitable rock bit was used for drilling shales and soft sands, and a more rugged rock bit was used for drilling hard sands. Reamers were employed only in the very hardest formations. A complete analysis of bit performance will be presented in a following section of this part of the report.

Fig. 3. Roberta Vaughn No. 1 during the course of deepening

3. Mud conditioning. The mud employed in the drilling of rotary holes performs other duties in addition to serving as a transportation agent for the cuttings from the bottom of the well to the top of the ground. It must serve as a cooling agent for the bit and as the lubricant for the bearings of rock bits. It also serves as a plugging agent for porous beds, and as such it must possess a viscosity, weight, and percentage of suspended matter sufficient to permit the deposition of a cake of mud over the face of such beds and thus prevent the flow of water, oil, or gas into the hole at a time when the operator is not prepared to take care of these products. Furthermore, the weight of the mud must be sufficient to offset the pressures that may be encountered in oil and gas reservoirs, thus preventing disastrous blowouts, and also preventing soft formations from caving into the hole. The properties of the mud may be built-up by the addition of various materials until it will conform to all of the foregoing requirements, but at the same time care must be exercised in maintaining its physical characteristics so that the fluid may be handled with facility by the pumps.

Fortunately, the conditioning of the mud, in connection with the drilling of the Travis Peak and Cotton Valley formations in the Vaughn well, was not a particularly difficult problem. Before drilling was begun a mud was prepared, using a weighting material, to obtain a weight of slightly over 9 lb. per gal. and a viscosity of about 20 Marsh seconds. This proved to be entirely satisfactory for the drilling of the top beds of the Travis Peak. To a depth of about 6900 ft. the shales in the Travis Peak ground-up into so much natural clay that it was necessary to add water continually to maintain a mud weight of about 9.5 lb. per gal. The only added material in this interval was in occasional treatments with a few sacks of material in order to keep the viscosity at an efficient point.

At a depth of about 6900 ft. a large surplus of mud of good consistency was available, but in the following sandy section of the Travis Peak, from 6900 to 7800 ft., considerable mud was lost by walling action, and also by contamination from crude oil that was used to free stuck drill pipe. It was necessary, therefore, to mix mud, using a local bentonitic clay and various additive materials, one of which was used to raise the average weight of the mud to about 10 lb. per gal. This weight, and a viscosity of from 21 to 23 Marsh seconds, was maintained to near the top of the Cotton Valley formation. When the first black shale made its appearance the mud weight was increased to 10.5 lb. per gal. When the well attempted to blow out at a depth of 8500 ft., drilling was discontinued for 24 hr., and then the mud weight was increased to about 11 lb. per gal.



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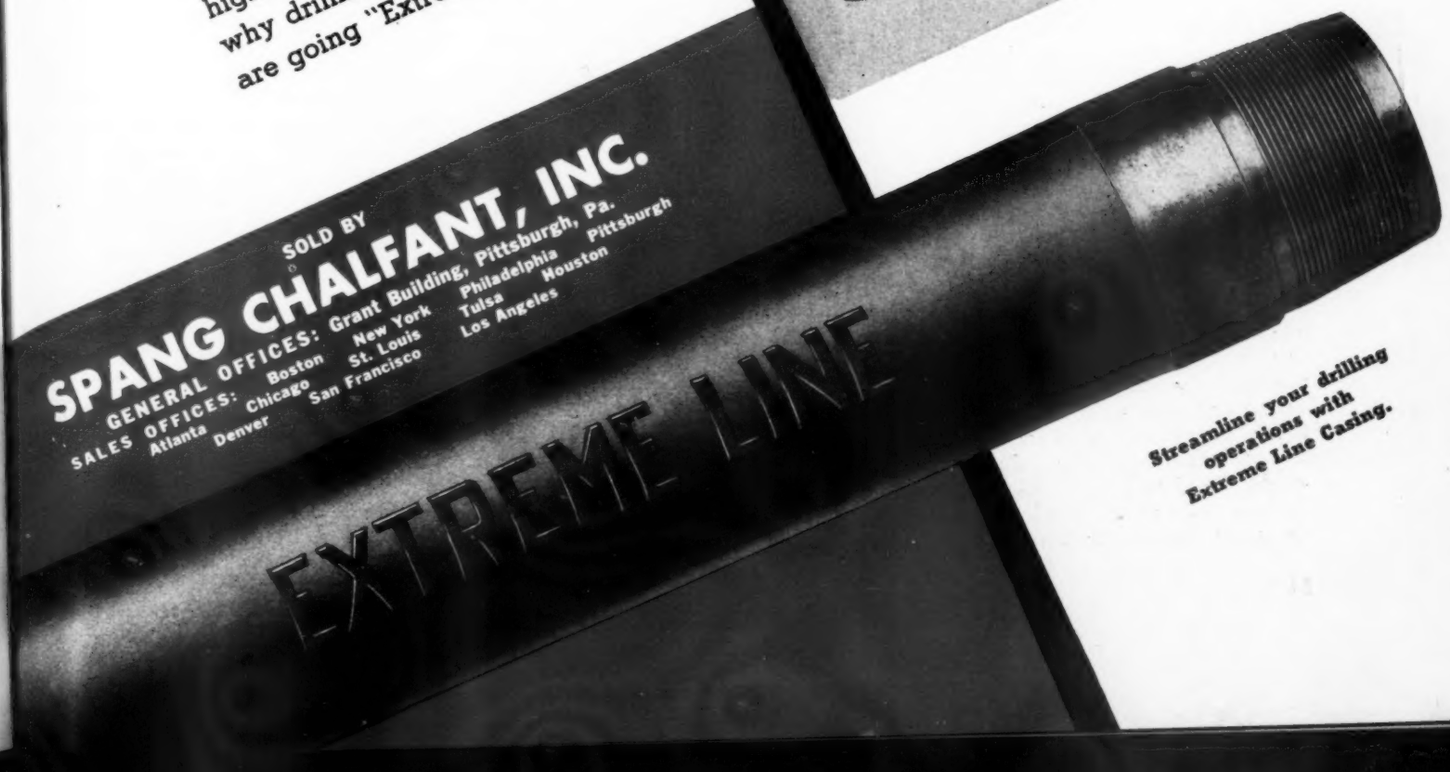

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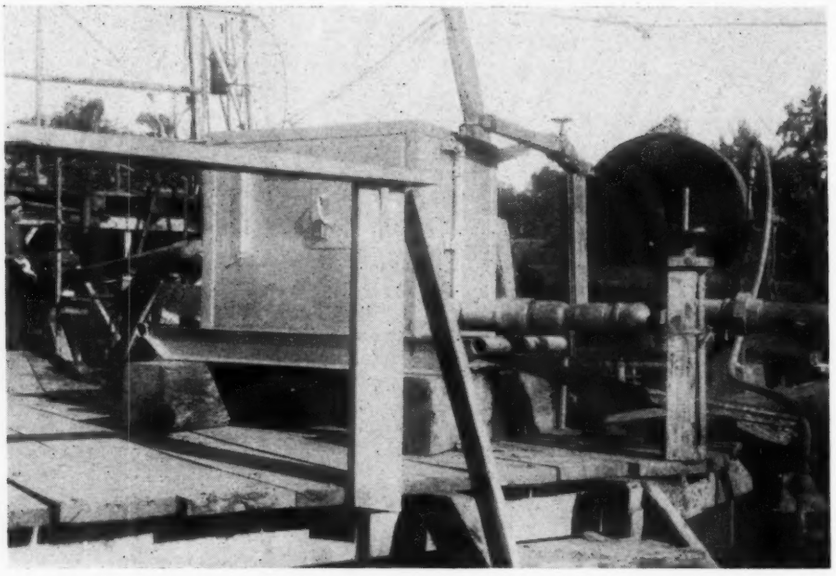


Fig. 4. Automatic sampling device used on Roberta Vaughn No. 1 well

The shales of the Cotton Valley formation are not good mud-making material, and inasmuch as considerable mud constantly was being lost through the formation of filter cake on the face of the permeable Lower Marine sands, it was necessary to add materials almost every day in order to maintain a proper mud consistency. At this point the viscosity of the mud was allowed to build-up to approximately 25 Marsh seconds in order to retard the formation of filter cake. This was partly successful, but at the same time it made the mud considerably more resistant to pumping.

Subsequent to the testing of the First Sand, the mud was in such poor condition, due to the admixture of ground-up cement and salt water, that the hole was completely cleaned-out with fresh water, and all of the old mud then removed from the pits. Fresh mud was prepared using a total of 220 sacks of purchased materials. This mixture of materials gave a mud weight of 10.6 lb. per gal., a viscosity of 23 Marsh seconds, and a filter cake of about ⅜ in.

In future deep drilling in the Lisbon field light-weight mud will prove to be entirely satisfactory until the sandy zone in the lower part of the Travis Peak formation is reached, inasmuch as no caving beds were found in this interval. The mud should be watched, however, in this part of the section and such water added as may be needed to keep it below the point of saturated fluid suspension. The mud weight should be gradually built-up in the lower part of the Travis Peak and the upper part of the Cotton Valley formations to a weight of 11 lb. per gal. in order to prevent blowouts, and also some caving of certain of the softer Cotton Valley shales. The colloidal properties of the mud should be closely controlled in this section to reduce as much as possible the loss of mud into the highly permeable sands and the consequent formation of filter cake on their faces.

4. Verticality tests. Verticality tests were made at convenient points during the course of deepening the Vaughn well. Every effort was made to keep the hole straight, and the record of these tests, given in Table 12, indicates that this was successfully accomplished.

TABLE 12

Record of verticality tests on the Roberta Vaughn No. 1 well

Depth, ft.	Deviation from vertical degrees
5525.72	1
5650.00	1
6215.00	1
6505.00	¾
7285.00	1
7538.00	1
7868.66	1
8500.00	1½

The straightness of the hole was undoubtedly an important contributing factor in the successful running of casing therein.

5. Sampling of drill cuttings. It was apparent from the beginning that it was essential to keep an accurate record of the formations encountered during the course of deepening the Vaughn well. Owing to the fact that samples of cuttings had to be supplied to five different companies, as well as for study at the well, it was important that the initial sample should be in large quantity as well as representative of the section drilled. For this purpose an automatic sampling device was installed, Fig. 4, this apparatus being connected directly to the main return mud flow line.

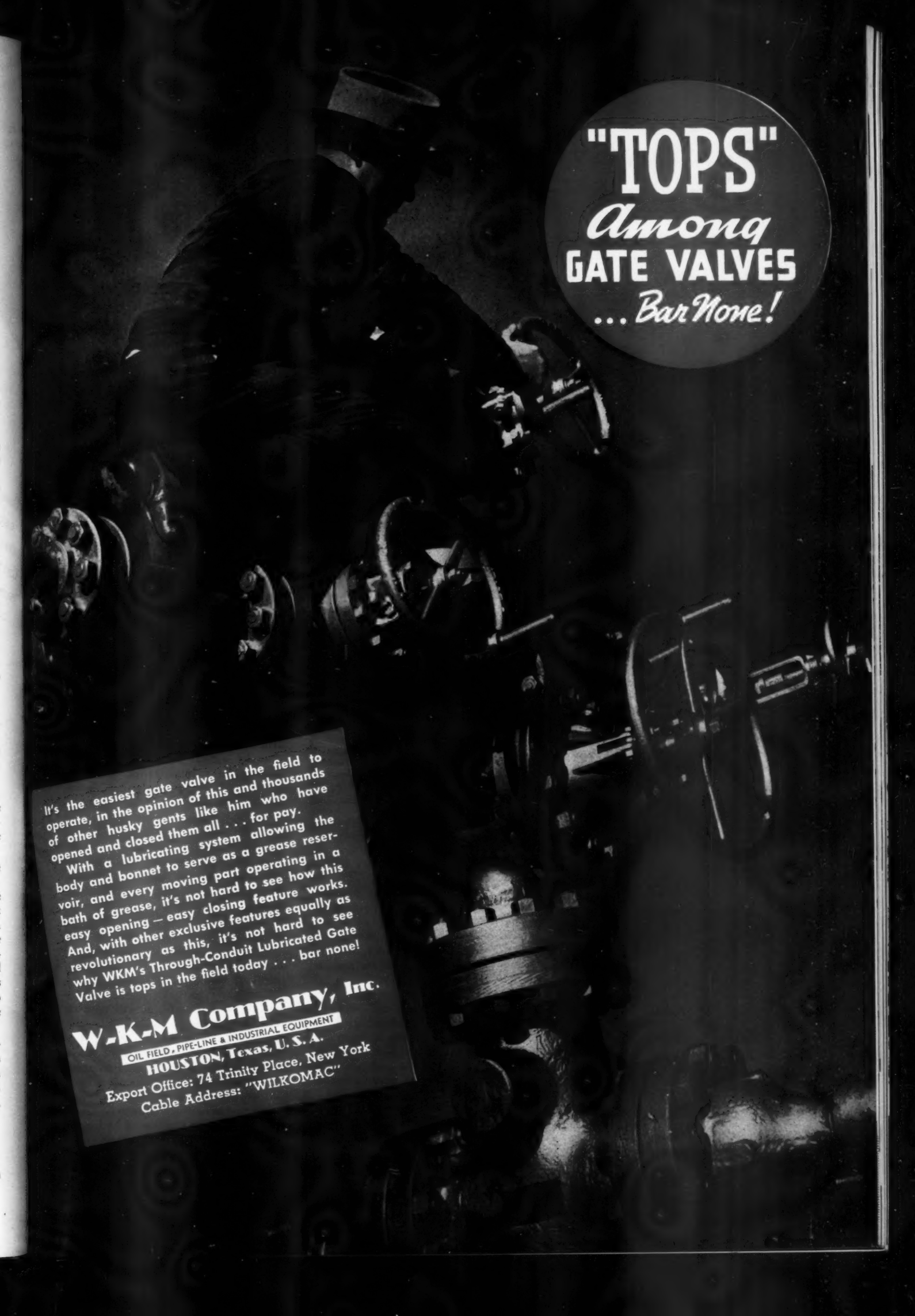
The operation of the sampling device is quite simple. The main stream of mud passes by a large vertical paddle wheel that is rotated by the current of the mud stream. This paddle wheel, through a series of geared connections, in turn rotates a long cylindrical screen that is set in a container along the side of the apparatus and at right angle to the paddle wheel. Just ahead of the paddle wheel, on the return mud flow line, there is a sliding type of diversion valve that turns a small part of the mud into the rotating screen. This screen slants slightly in the direction of flow of the mud stream, and the container in which it is set is equipped with a series of fine water jets, which spray water through the screen as it rotates, and thereby washes the drill cuttings free from mud as they pass through. The force of the water from the jets and the inclination of the screen carries the clean cuttings to the lower end of the screen where they drop into a small inclined trough, and are then washed downward by a small water jet into a metal box having a screen bottom, which is attached to the lower frame of the apparatus.

The sampling device provides absolutely representative cuttings between any depths desired, but it has the disadvantage that it will not accumulate cuttings from soft, fine-grained sands. For this reason it was at times necessary to supplement the sample so collected with cuttings obtained from the shale shaker in order to provide a sample of sufficient size for the purpose required.

Samples, for the greater part, were collected between 10 ft. depth intervals, but in important zones they were collected at 5 ft. depth intervals. At points where it was suspected that a sand had been encountered it was the customary practice to discontinue drilling and circulate the mud for a period of time sufficient to bring the cuttings from the bottom of the hole to the top of the ground where they would be subject to immediate inspection.

The samples were continuously examined at the well, and the formation record plotted each day in conjunction with the time log. This served as a valuable record, available at all times, for purposes of correlation.

Editor's Note: This article will be continued in an early issue.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Destructive Hydrogenation Improves Product From Inferior Hydrocarbons

Rearrangement of molecular structure by cracking, followed by addition of hydrogen by hydrogenation prevents polymerization of tar and coke and results in a marketable gasoline

By RAFAEL FUSSTEIG

THE demand for motor fuels has been so great during the last few years that petroleum investigators have been spurred to intensive study of all possible methods of increasing the yield of these products. One result of these studies has been the development of what is known generically as the hydrogenation process. The hydrogenation process used in the production of gasoline-like hydrocarbons differs entirely from the simple hydrogenation process. By simple hydrogenation process is meant solely the addition of hydrogen to the molecule without any dearrangement of basic construction, whereas the hydrogenation method used in the oil refining industry, the so-called destructive process, is a combination of pyrolysis and simple hydrogenation, the latter taking place after the rupture of the molecule. In other words, destructive hydrogenation is a combination of the cracking process and simple hydrogenation.

The essential characteristic of the cracking process lies in the fact that there are always formed, along with the light hydrocarbons, products that are enlarged in *statu nascendi* with hydrogen that is split from the second part of the molecule. As the crude oil contains about 14 percent disposable hydrogen, the second part of the split molecule is transformed into polymerized heavier hydrocarbons, such as tar and coke. In destructive hydrogenation these polymerization processes may be prevented so that only light products are obtained. In other words, the addition of hydrogen at the instant the molecules are split, prevents the polymerization and condensation of unsaturated hydrocarbons.

For this purpose high temperatures and pressures must be employed, the reactions obtained being dependent upon these factors. The reactions can be determined easily by the mathematical expression of Nernst:

$$\log K = \frac{Q}{4.57T} - n\ 1.75 \log T - nC_1$$

where

Q = the heat of vaporization of the given reaction

n = the algebraic total of molecules taking part in the reaction, the disappearing molecules being denoted by the plus sign and the appearing molecules by the minus sign

nC = the algebraic total of products of the chemical constants by number of molecules

RAFAEL FUSSTEIG

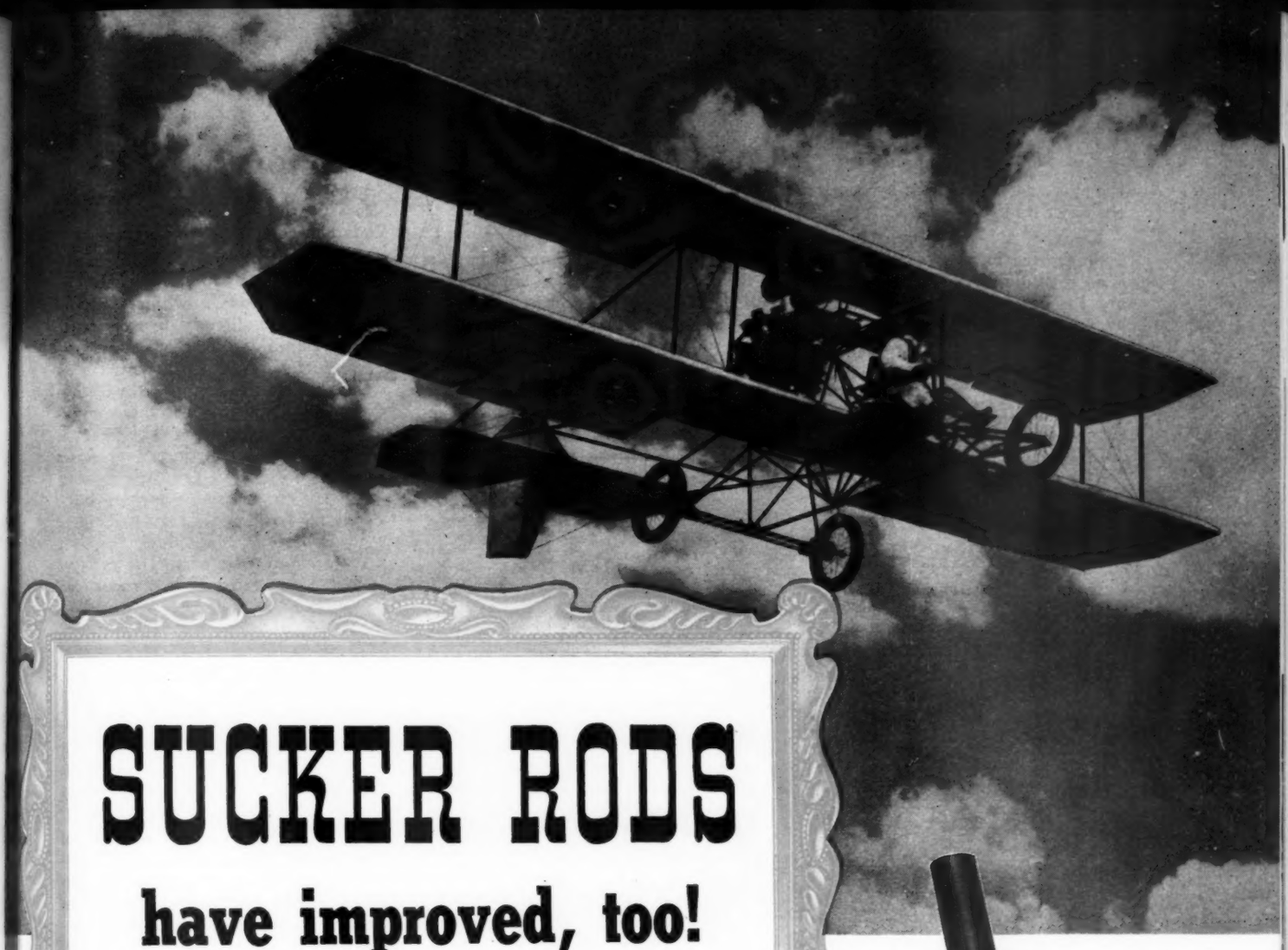
together with his family, is now in Lwow, Poland, having been obliged to leave his headquarters in Jaroslaw when that city was occupied by the German army—He hopes soon to come to the United States to establish his permanent residence—Prior to the outbreak of the war in Europe he was professor of petroleum technology in the Ecole Superieure Technique et Commerciale de Paris, Paris, France, and maintained an office as consulting petroleum engineer at Jaroslaw, Poland.

The calculations by means of the Nernst expression prove that the values of log K for olefins are positive even at a temperature of 477°C., that is to say, that the addition of the hydrogen into the olefins can be easily carried out. As the values of log K at 200°C. are very large this addition can be carried out without high pressures. The addition of cyclic and aromatic hydrocarbons, however, shows a different character. The values of log K for these reactions are positive only at a temperature of 200°C. At temperatures above 300°C. the cyclic and aromatic compounds show a negative value that brings about the reverse process, dehydrogenation. High pressures, therefore, must be used to attain the equilibrium constant of these reactions. According to this phenomenon, it is very easy to hydrogenate only the unsaturated hydrocarbons of petroleum, the aromatic hydrocarbons being unattached because a lower pressure is used.

It must be noted, however, that the length and the isomerization form of a hydrocarbon play important parts in the destructive hydrogenation process. The longer the hydrocarbon chain the more it resists hydrogenation. Besides, the longer the hydrocarbon chain, the more it must be split prior to hydrogenation. This must be carried out to obtain hydrocarbons, which after hydrogenation could be transformed into gasoline-like hydrocarbons. In destructive hydrogenation not only are the abovementioned hydrocarbon types submitted to this destructive reaction but the paraffinic hydrocarbons of longer chains can also be split into gasoline, the remaining unsaturated hydrocarbon being enriched at the same time by outside hydrogen, thus preventing its polymerization and condensation to higher-molecular hydrocarbons, tar and coke.

These reactions cannot be easily carried out, however, because the hydrogenation velocities are too low to prevent polymerization and condensation reactions. Likewise, the longer hydrocarbon chains encounter trouble in the hydrogenation process, that is, the yield of gasoline decreases as the molecular weight of the hydrocarbons increases.

Temperature and pressure must be increased, therefore, to attain hydrogenation. Unless these factors are increased, the velocity of the reaction is too low, and the process will tend to produce gaseous hydrocarbons on the one hand, and hydrogenated, unsaturated liquid hydrocarbons on the other. It is necessary, therefore, to increase the reaction of hydrogenation in a manner that permits the split dehydrogenated hydrocarbons to be easily completed by the addition of hydrogen at the moment they attain their *statu nascendi*. Thus it follows that the lower



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the molecular weight of a hydrocarbon the easier its hydrogenation.

Kerosine and gas oil can be easily hydrogenated but heavy oils are processed with difficulty. The writer's theory accounting for this is that each hydrocarbon when submitted to pyrolysis is first split into hydrogen and labile carbon atoms of two active linkages and is then combined into active labile $=CH_2$ molecules, which are the starting material for the formation of different types of hydrocarbons.

In the destructive hydrogenation reactions of light hydrocarbons such as kerosine and gas oil, the volume of the remaining split carbon atoms (the carbon atoms that have no more disposable hydrogen) is relatively small. Consequently, their condensation and polymerization require a comparatively longer time, that is to say, they are active a longer time; as a consequence imported hydrogen atoms enter easily into reaction with these carbon atoms. Thus the more split carbon atoms in the same reaction field the easier it is to obtain the condensation and polymerization reactions; conversely, their hydrogenation is more difficult. This can be explained by the fact that a volume of gas oil when submitted to the pyrolysis will have fewer carbon atoms remaining in the reaction field than will the same volume of a cylinder stock, under the same conditions. Likewise, charcoal will show more carbon atoms remaining than a cylinder oil. In other words, the concentration of split carbon atoms plays a most important role in this process. The higher the concentration of the carbon atoms the more difficult is their hydrogenation. The reason for this is that when the concentration exceeds a maximum the carbon atoms are not able to fluctuate in the free labile state, resulting in their instantaneous polymerization and condensation.

When charcoal is submitted to a destructive hydrogenation, only higher-molecular liquid hydrocarbons will be formed. The reason for this lies in the concentration of the split carbon atoms. Thermodynamically it can be explained that the hydrogenation velocity is too low in this instance to permit completion with hydrogen atoms. Even the use of high temperatures and pressures does not increase these velocities. The increase of the hydrogenation velocities can be obtained, however, by using proper catalysts.

Not only is the velocity important in the hydrogenation reaction but it is also essential that proper cracking reactions be used in the destructive process. The purpose of a proper catalyst is to increase the cracking velocity. In other words, the cracking reactions must be conducted so that a minimum amount of gaseous hydrocarbons is formed in this process. Of course, the decomposition reactions must be accelerated to permit the hydrogenation reactions to precede the polymerization and condensation of the carbon atoms. It may be concluded that only by use of a catalyst is it possible to overcome all the abovementioned difficulties. It has been stated that in all hydrogenation operations the use of a catalyst permits the decrease of pressure from 1000 to 200 atmospheres, at the same temperatures. In other words, without the use of a catalyst, a pressure of 1000 atmospheres and a temperature of about 500°C. must be used, but in the presence of a proper catalyst a pressure of 200 atmospheres and a temperature of about 450°C. accomplish the same results. Under these conditions the olefinic and cyclic hydrocarbons can be properly decomposed and then completed with hydrogen.

The saturated hydrocarbons show a quite different conduct. While the olefinic hydrocarbons can, under certain conditions, be directly hydrogenated, the paraffinic hydrocarbons must first be split into small unsaturated particles that are then completed with hydrogen. The splitting becomes complicated as the molecular weight increases —the content of hydrogen decreases and the concentration of carbon atoms increases. The reaction velocities must, therefore, be properly regulated. Here also the action of a proper catalyst plays an important part. The catalyst effect on saturated hydrocarbons can be expressed as follows:

(1) A reduction of the optimum temperature for a favorable yield of gasoline will be obtained by accelerating the gasoline molecule rupture.

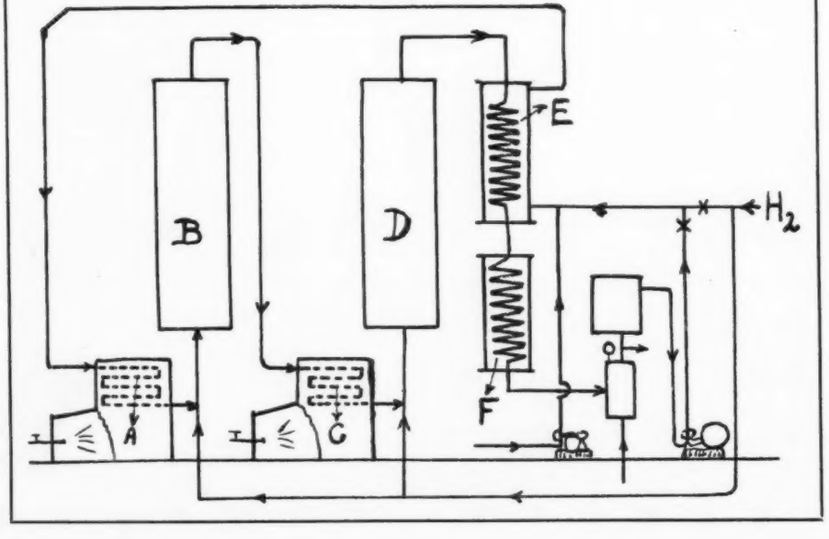
(2) Highly saturated hydrocarbons will be obtained by accelerating the hydrogen addition. This is because the hydrogen addition parallels the velocity of the rupture.

Each crude oil as well as charcoal contains varying combinations of sulphur, oxygen, and nitrogen that must be removed from the hydrocarbon. The catalyst is able to isolate these compounds in the hydrogenation process, transforming them into hydrogen sulphide, water, and ammonia. These reactions hindered initial research in the field of hydrogenation as the sulphur and nitrogen were adsorbed on the surface of the catalyst, causing its poisoning. Research by many investigators has resulted recently in the development of a large number of catalysts, among which are several nonpoisoning types employing metallic sulphides, especially those of molybdenum, tungsten, and cobalt.

Even these improved catalysts encounter difficulty in the hydrogenation process. For instance, when a heavy oil is subjected to hydrogenation, it is possible to transform it completely into gasoline when using a relatively small throughput and very low partial pressure of products. If either the throughput or the partial pressure of the products is increased, the activity of the catalyst will be retarded, resulting in a decrease in the final volume of the gasoline formed.

These difficulties arise for two reasons: 1. The higher-molecular compounds of the charging stock are adsorbed by the surface of the catalyst in the beginning of the process, contributing to the isolation of the other hydrocarbons. 2. The higher-molecular compounds are dehydrogenated and

Fig. 1



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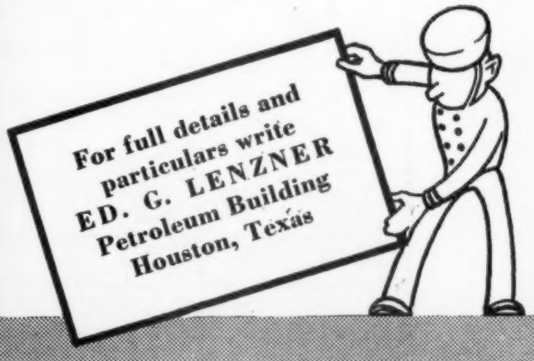

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polymerized at a higher partial pressure. As a result, these compounds will be transformed into hydrocarbons that cannot be split, being finally retained on the surface of the catalyst. These reactions cause a decrease in the activity of catalysts.

To obviate these difficulties the process must be divided into two stages, liquid phase and vapor phase. In the first liquid-phase treatment, the higher-molecular-weight hydrocarbons will be split and hydrogenated into middle-molecular compounds, these being then split and hydrogenated to gasoline in the second vapor-phase treatment. Of course, a corresponding catalyst must be employed for each phase. The catalyst used for the liquid-phase hydrogenation must maintain a satisfactory hydrogen concentration, because a high velocity of hydrogenation is necessary at a temperature of about 300°C. to prevent the dehydrogenation and polymerization of the split higher-molecular hydrocarbons. The catalyst depends somewhat upon the nature of the raw materials and usually is added in admixture with the charging stock. As far as vapor-phase hydrogenation is concerned, it depends largely upon a variety of factors. For example, the temperature and the pressure of the hydrogen influences the degree of hydrogenation; being increased by increasing the hydrogen pressure, and decreased by raising the temperature. Here the catalyst is able to transform all split molecules into gasoline of high quality. It (the catalyst) is suspended inside the converters and selection is based upon the nature of the final products desired. By careful control of temperature, pressure, catalyst, and time of reaction, it is possible to produce products of high quality. From this it may be concluded that the hydrogenation of kerosine, gas oil, and other middle-molecular-weight hydrocarbons can be hydrogenated only in a one-phase system, that is, in the vapor-phase, because the split particles are completed with hydrogen to form gasoline.

On the contrary, the higher-molecular oils must be submitted to the two-phase system. That is, they must first be hydrogenated into middle-molecular hydrocarbons, these being then hydrogenated into gasoline. As far as charcoal is concerned, the destructive hydrogenation process must be carried out in three phases; in the first phase, the hydrogenation of the charcoal must be executed in the liquid phase, where the oil-coal paste is treated at temperatures of 400°-460°C., and under a pressure of 200 atmospheres. The reaction is arrested at a point where the final product is mainly heavy oil. In the second phase the hydrogenation of this heavy oil must be once more incurred in the vapor phase at a temperature of 450°C. and under a pressure of 250 atmospheres to produce a middle oil. In the third phase, the vapor-phase hydrogenation of the middle oils transforms them into gasoline of high quality.

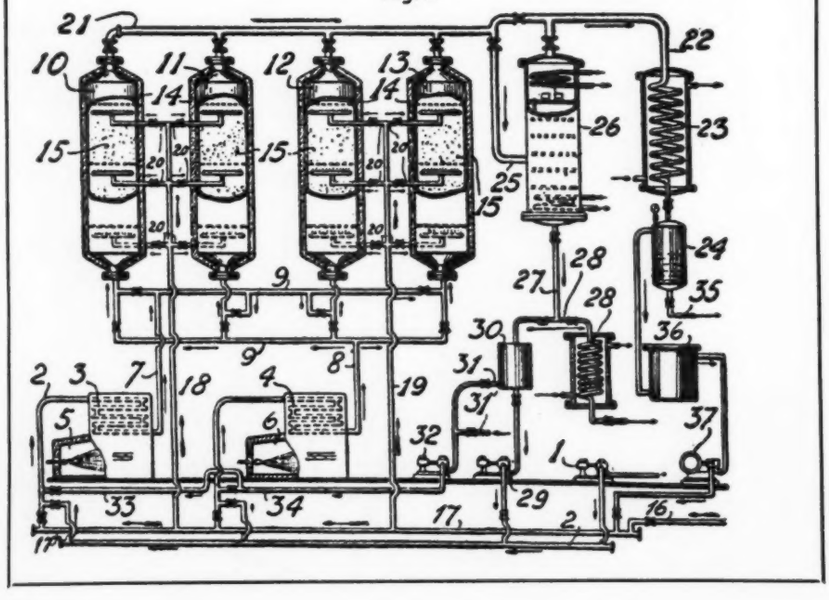
Separation of the process into stages serves to eliminate both of the aforementioned difficulties. In the liquid-phase treatment, hydrogen concentration of 70 percent can be satisfactorily maintained and the catalyst is not called upon to activate reactions producing light oils. In the vapor-phase treatment, a hydrogen concentration of over 85 percent can readily be maintained, and the dehydrogenation and polymerization of the reaction products are thus prevented. Consequently the charging stocks for hydrogenation can be divided into three types: 1. The liquid middle-molecular-weight hydrocarbons that can be directly hydrogenated to gasoline; 2. the liquid higher-molecular hydrocarbons that first must be hydrogenated to middle-molecular hydrocarbons, and 3. the higher-molecular solid hydrocarbons that first must be transformed into liquid higher-molecular hydrocarbons, being then hydrogenated into middle-molecular hydrocarbons.

The hydrogenation process can also be used in the cracking of oils. During the cracking process certain unsaturated hydrocarbons are formed that cause the deterioration of the gasoline quality. These hydrocarbons can be transformed into valuable saturates by means of the hydrogen addition. Of course, the presence of a proper catalyst accelerates the velocity of this saturation. Without use of a catalyst, the reaction proceeds very slowly, resulting in the transformation of only 50 percent of the olefins into saturated hydrocarbons. The thus saturated hydrocarbons show a boiling point below 100°C.

The second characteristic reaction of the cracking process with the partial hydrogen addition is that of purification. Sulphur, nitrogen, and oxygen cannot be removed from the hydrocarbon during the cracking process, thus deteriorating the cracking products. These compounds, however, are preferentially attacked by the hydrogen, and these reactions occur so vigorously that they leave the reaction zone as the corresponding gaseous hydrides. Thus this process may be termed chemical purification. The gasolines produced by this combined process are, therefore, characterized by low sulphur and gum contents.

It can easily be seen from the above that the cracking process combined with partial hydrogen addition not only increases the yield of gasoline but also produces a nearly pure hydrocarbon mixture. Such a gasoline, therefore, requires no finishing treatment other than a caustic or soda wash, followed by a light doctor sweetening. Furthermore, the gasoline produced by means of the abovementioned process has high volatility and contains 40 percent of hydrocarbons having a boiling point of 100°C. Further, not only do the saturation of olefinic hydrocarbons and the purification take place but also the formation of the split gaseous hydrocarbons will be decreased by half. The reason for this is that the hydrogen-addition-cracking system prevents the

Fig. 2



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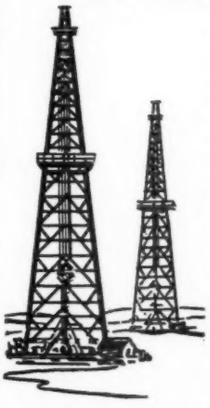

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rupture of gaseous hydrocarbons. Besides, the yield of fuel oil also decreases in this process by about half. This is because the remaining free carbon atoms having two active linkages enter into reaction with the hydrogen from the artificial hydrogenation.

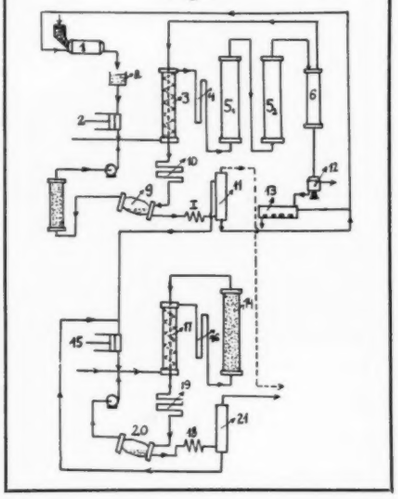
There are many patents involving the hydrogen-addition-cracking systems, the patent of the Standard Oil Development Company and that of Black and Chappell being the most interesting processes. The first process, invented by W. L. Gomory[1], operates in such a manner that the condensate from the cracking process, passing to the central part of a vertical evaporator is submitted to a hydrogenation process, the hydrogenated products being then directed to the lower part of the same evaporator. In this method the split gaseous hydrocarbons from the cracking process can be used as the hydrogenation material instead of hydrogen because they are very rich in hydrogen content. The second method, invented by Black and Chappel[2], treats the higher boiling oils in the cracking phase at a temperature of about 450°C. and under a pressure of about 15 atmospheres. The rearranged hydrocarbon vapors are then cooled to about 400°C. At the instant the vapors reach this temperature, hydrogen will be produced, which saturates the unsaturated hydrocarbons.

From the above it may be concluded that this combined cracking process differs entirely from the true destructive hydrogenation process. These differences rest in the fact that the destructive hydrogenation process simultaneously decomposes and hydrogenates the hydrocarbon molecules, but in the combined cracking process, the hydrogenation takes place after the rearrangement of the hydrocarbon vapors. In other words, the combined cracking process is unable to influence the flow of the destructive hydrogenation of the starting hydrocarbon molecule, being able only to hydrogenate and stabilize the unsaturates and the remaining unattacked split hydrocarbon particles.

As mentioned, the destructive hydrogenation of petroleum is carried out in two stages: in the first stage the oil is split into smaller particles, these being then hydrogenated in the second stage. This process can be considered as a much better method than the cracking process because the first yields more than 100 kg. of liquid products from 100 kg. of starting material, but the latter yields considerable volume of gas, tar, and coke. In a modern two-phase system it is possible to transform heavy oils into gasoline of a high octane number. In the first phase the higher-molecular hydrocarbons will be split and hydrogenated into middle-molecular hydrocarbons, and in the second phase the middle-molecular hydrocarbons will be split and hydrogenated into lower-boiling gasoline. A somewhat simplified flow diagram of this process is shown in Fig. 1[3].

In Fig. 1, the heavy starting oil, mixed with hydrogen under a pressure of 200 atmospheres, is directed to heater A in which it is heated to a temperature of 280°C. The heated mixture is then introduced to the reaction chamber, B, where the rearrangement and hydrogenation occur. The reaction chamber B is filled with a catalyst in the form of small cubes. As catalysts, sulphides, oxides, or nitrides of the metals from the sixth group of the periodical system are used

Fig.3



in this process. The hydrocarbon vapors rearranged and hydrogenated in B are then directed to the heater, C, where they are heated to a temperature of 540°C. Then the vapors pass through the second reaction chamber, D, which is also filled with a suitable catalyst. In the latter reaction chamber the second rearrangement and hydrogenation occur, resulting in the formation of gasolines. The gasoline vapors thus formed then pass through the heat exchanger, E, and cooler, F, to be condensed.

The apparatus, however, has a few disadvantages. During the operation, reaction conditions may change quickly, especially in the gas-phase (that is, in the second reaction chamber). Temperature fluctuations of the starting material may occur, resulting in changes in the composition of the gasoline formed. Slight changes of the starting oil temperature in the heater will cause appreciable changes in the reaction chamber temperature as exothermic reactions occur therein. These difficulties can be avoided by using several reaction chambers in each phase and then mixing the several products. Fig. 2 shows the modified process of the abovementioned patent.

In Fig. 2 the starting material is directed by means of the pump (1) to the heater (5) or (6), being heated preferably to a temperature of 370°-425°C. in the coils (3) and (4), but never above 510°C. The heated starting oil passes through the reaction chambers (10), (11), (12), and (13), which are filled with suitable catalysts. These reaction chambers are, of course, covered with a thick layer of non-conducting material. Simultaneously, hydrogen, introduced in the reaction chambers, enters into chemical reaction with the split hydrocarbon molecules. This reaction causes a heat evolution, resulting in the increase of temperature to 485°-550°C. The temperature in the reaction chambers can be regulated by varying the hydrogen addition at the various points in the reaction chambers. The reaction products from this process are fractionated in the fractionating tower (26) into liquid and gaseous fractions.

The liquid fraction is drawn off from tower (26) through the cooler (28) or it can be collected in the vessel (30), after which it can be pumped, alone or mixed with the primary starting oil, by pump (29) to the heaters. The fractionated gases from the tower (26) pass overhead to the cooler (23), where a separation of the condensed hydrocarbons from the gases occurs. These gases then pass through vessel (36), wherein they are purified, prior to being used as hydrogenation material. The gases containing hydrogen principally, as well as methane, ethane, etc., are removed by absorption or washing. The purified hydrogen is then mixed with the other hydrogen material. Condensed gasoline passes through (35) to a vessel not shown in the sketch. Under favorable conditions the yield of gasoline of a high octane number may exceed 90 percent.

As mentioned, the destructive hydrogenation of solid hydrocarbons must be carried out in three phases. This high-pressure hydrogenation process is the result of developments extending over more than 20 years. This process patented by the I. G. Farbenindustrie. A.G. has been in commercial operation

[1]English Patents 359023-27.
[2]U. S. Patent 1,820,371.
[3]Gitteitungen der techn. Abt. der Standard I. G. 1932.

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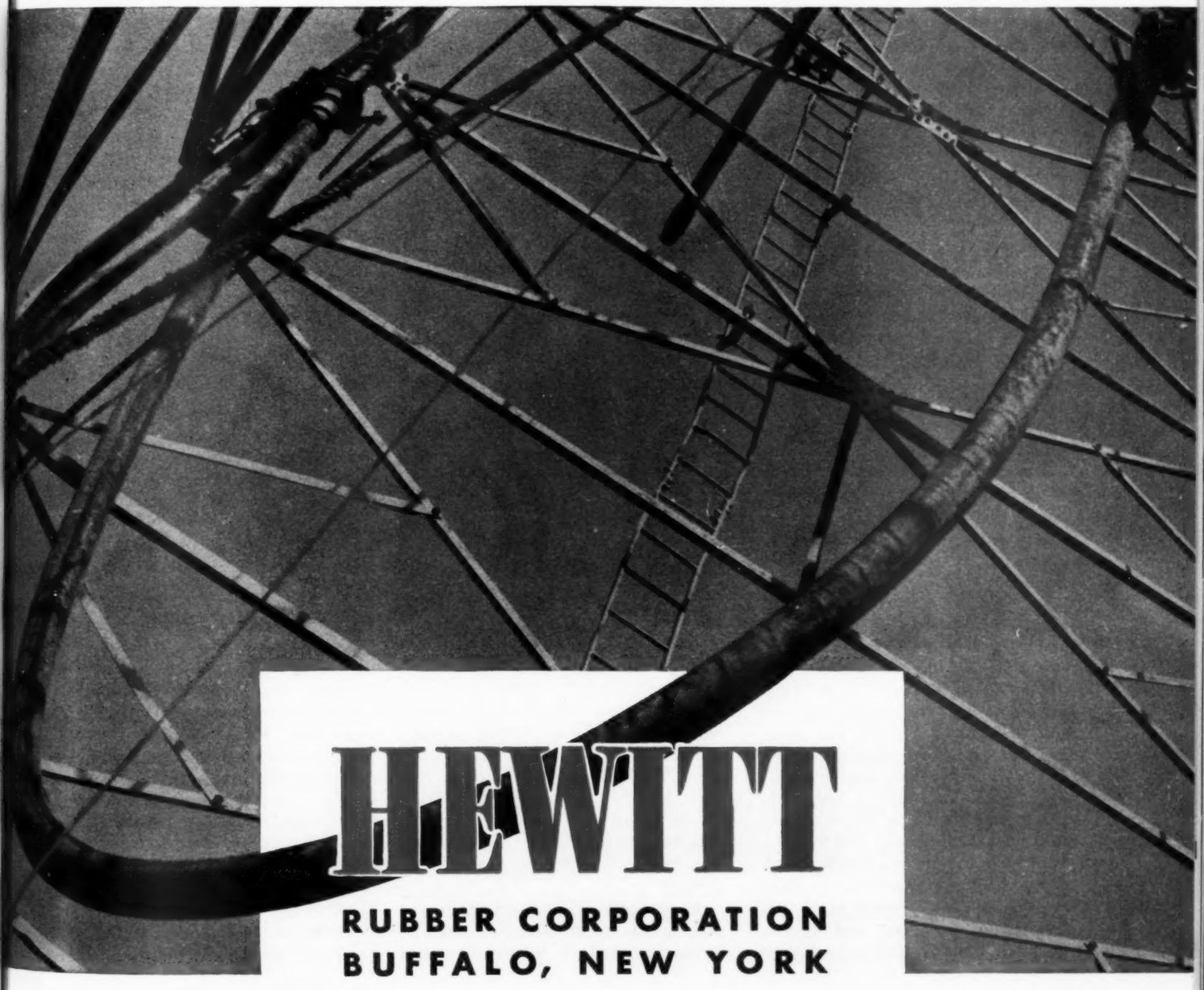

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during the last 10 years. Fig. 3 shows the characteristics of the high-pressure hydrogenation of solid hydrocarbons such as charcoal, etc.

The coal is first broken up in the mill (1) and then mixed with heavy oil. The coal slurry is directed to the vessel, *a*, where a portion of the catalyst (which has been made into a paste with oil) is added. This paste, containing about 60 percent solid substance, is drawn by the high-pressure pump (2) through the heat exchanger (3) to the heater (4), wherein this starting material is mixed with hydrogen under a pressure of 300 atmospheres. In this heater the coal slurry and the hydrogen are heated to a temperature of about 400°C. Entering the reaction retorts (5_1) and (5_2), the temperature of the material is increased rapidly, because of the exothermic hydrogenation reactions to about 460°C. At that temperature the coal is split into certain particles under the influence of the admixed catalyst and of the highly compressed hydrogen. Thus coal will be transformed into liquid higher-molecular hydrocarbons. The pressure and the catalyst, however, aid in decomposing these higher-molecular hydrocarbons into new molecules in the same phase, so that, upon the addition of further hydrogen, middle-molecular hydrocarbons may be obtained. This is the reason that two reaction retorts are used in the first phase of this process. In the first retort, coal is transformed into liquid higher-molecular hydrocarbons; in the second retort, these are rearranged and transformed into middle oil. Of course, simultaneously a certain amount of gasoline together with small quantities of gaseous hydrocarbons are also produced in the first phase.

The products of the hydrogenation reaction of the first "liquid-phase" pass through a separator (6), in which the same temperature prevails as in the reaction retorts (5_1) and (5_2). This middle oil contains heavy oils, residual coal, ash, gas, and middle oil. The middle oil leaves separator (6) in vapor form and goes to the heat exchanger (3) and the condenser (10). The cooled hydrocarbons pass through the stripper (9), wherein hydrogen and the gaseous hydrocarbons are separated. The oil obtained is directed to the heater (I) and then to the distillation tower (11), where it is fractionated into heavy oil, middle oil, and gasoline.

The heavy oil is directed to the low-temperature retort (13), and the middle oil and the gasoline are subjected to further treatment. The residuum from separator (6) containing heavy oils, residual coke, and ash is directed to the centrifuge (12) and centrifuged. The oil contained in the residue after centrifuging is also separated in (13) by heating the oil with steam. The heavy oil regained by low-temperature carbonization, centrifuging, and stripper distillation serves for the preparation of fresh coal. The gas containing hydrogen and other compounds leaves the stripper (9) and goes to the gas-purification scrubber in which it is freed of all hydrocarbons that have been formed and is reintroduced into the reaction cycle after admixture of fresh hydrogen.

As seen in Fig. 3, gasoline vapors from the first-phase leave the distillation tower (11) overhead; the middle oil is taken from the tower by the oil-injection pump (15) to the heat exchanger (17), and then into the heater (16), where it is heated to 400°-520°C. under a pressure of 300 atmospheres. Then the heated starting middle oil enters the light-oil retort (14), which is filled with lumps of the catalyst. The conversion of the middle oil into gasoline occurs in this retort. These converted vapors then pass through the heat exchanger (17) and the condenser (19). After this, the product enters the stripper (20) wherein the separation between the gas and the condensed hydrocarbons takes place. The hydrogen is returned to the cycle, and the gasoline is directed first to the heater (18) and then to the fractionating tower (21). The gasoline is now in marketable form as motor gasoline.

According to Schlattmann and Koppenberg, the middle oil can be treated at the comparatively low temperature of 400°C. with strongly hydrogenating catalysts, or, at higher temperature (500°C.) treated with a catalyst that hydrogenates less strongly, according to the type of gasoline desired. In the former case, the light oil produced, having higher hydrogen content, generally possesses lower antiknock quality; in the latter case, aromatic gasoline is produced having little hydrogen content. The former must be washed with lye; the latter may be refined and redistilled as desired.

As mentioned, the hydrogenation of hydrocarbons yields certain amounts of gaseous hydrocarbons. These hydrocarbons contain very large volumes of hydrogen and it is of great economic importance to control all the hydrogenation reactions to minimize this formation. In the event, however, that small amounts of hydrocarbons are formed in this process they can be used in the cycle as a hydrogenation material. Furthermore it is important to know the qualities of hydrogen necessary to hydrogenate a corresponding starting material. Table I shows the theoretical hydrogen consumption, providing that no gas formation occurs[4].

TABLE I.

	Middle oil, cu. m. per ton	*Gasoline, cu. m. per ton*	*Kerosine, cu. m. per ton*
Crude oil:			
Rich in hydrogen, entire	50	120	....
Rich in hydrogen, middle oil	....	70	30
Poor in hydrogen, entire	200	400	....
Poor in hydrogen, middle	....	200	210
Brown coal:			
Coal	900	1220	....
Coal-middle oil	....	310	375
Black coal:			
Coal	680	1100	....
Coal-middle oil	....	420	500

The hydrogen consumption depends largely upon the hydrogen content and the composition of the gas formation. In other words, the more hydrogen a hydrocarbon contains the easier its hydrogenation. Thus the easiest is the hydrogenation of gas oil and the most difficult is the hydrogenation of coke. On the other hand, the lights oils when hydrogenated yield more gasoline than the solid hydrocarbons. From this, it may be concluded that this process is able to carry out all reactions that are impossible to achieve in the cracking processes.

[4]Petroleum: Krauch and Pier, 1932, No. 34.

The Stabilization Process of Natural Gasoline Extraction

A PETROLEUM ENGINEER EXCLUSIVE FEATURE

Regulation of top and bottom temperatures and pressures governed by the proper type of instruments facilitates close control of finished product

By ROY W. MACHEN
Superintendent, Hamman Exploration Company

THE gradual development of a demand by refiners for a well-behaved natural gasoline to replace the "wild casinghead" of the early years of the industry was the cause of the gasoline-plant operator adding another process unit to his plant.

Stabilization, whereby the high vapor-pressure, raw gasoline is stripped of its lighter and undesirable hydrocarbons and brought to any desired specification, is that process. Stabilization is essentially the "taming" of the normally "wild" raw gasoline.

The term fractionation, although usually applied to the separation of petroleum fractions in the making of chemically-pure products, is commonly used synonymously with the term stabilization. Although the two terms are not synonymous, no serious error is involved because we do make a separation of groups of fractions. Stabilization like the absorption and distillation processes, is essentially an equilibrium phenomenon and is accomplished in much the same manner as was separation of the raw gasoline from the absorption oil in the distillation unit.

The stabilization system is composed of a fractionating column of the "bubble-cap" type and has 26 to as many as 40 plates or decks. The number of trays depends on the degree of fractionation desired and the reflux ratio that will be the most economical and advantageous. In conjunction with the main column there must be conventional heat exchangers, a reboiler or kettle, reflux accumulator, finished-product and reflux coolers and condensers, temperature controls, back-pressure regulators, liquid-level controls, feed and reflux pumps.

The stabilization system may consist of only one column and the auxiliary equipment mentioned, or it may be a series of columns having supplementary equipment for each column. The number of columns will depend on the number of partitions or divisions that will be required in processing the raw gasoline. Because of the increased demand for liquefied gases and the greater margin of profit when making the separation of the butanes and propanes for this purpose and for further processing in polymerization units, the equipment may economically be of high-pressure type, designed for a working pressure of approximately 300 lb. This use of high-pressure equipment is essential because in the fractionation of such volatile liquids as propane and butane, the column pressure must be such that a practicable top temperature can be maintained to permit the lighter component to exist as a liquid at that temperature.

ROY W. MACHEN

received a bachelor's degree from Oklahoma City University in 1927—Employed for six and one-half years by the Peppers Gasoline Company as refinery clerk, refinery and gasoline plant chemist, and gas engineer—The last six years have been spent in the service of various independent refining companies as gas engineer, operator in high-pressure gasoline plants, refinery construction engineer, and superintendent of refinery operations—He is a registered petroleum and natural gas engineer—Recently he was promoted to superintendent by the Hamman Exploration Company.

Selection of Feed Inlet

The raw gasoline is pumped from the "surge" or make tank through the heat exchangers countercurrent to the outgoing finished product from the kettle. If insufficient heat is obtained in the heat exchangers to bring the raw feed to the desired temperature it is further heated by a preheater before being admitted to the tower on one of the several feed plates that are manifolded to a common header. The number of feed inlets may be as few as three and are as many in some cases as nine.

The proper feed inlet to be used depends on the composition of the feed and the amount of removal overhead. The proper point of admission for the raw product would be at the tray where the vapor pressure of the tray liquid is the same as the vapor pressure of the hot charge.

Mechanics of Stabilization

There is a temperature gradient up the tower, the plate or deck temperature progressively decreasing from the bottom to the top. The liquid on each successive tray from bottom to top is progressively richer in the lighter components and poorer in the heavier components. As the temperature of the liquid on each deck is that at which the vapor pressure of the liquid is equivalent to the column pressure, any slight increase in heat will disturb the tendency toward equilibrium and cause vaporization of the lighter components.

The raw gasoline, like the rich oil in the distillation process, is externally heated as it is pumped at a uniform

rate through a continuous coil, in this case the heat exchangers and connecting piping. The pressure in the coil is held mechanically in excess of the vapor pressure of the heated charge. Immediately as the hot charge stock is introduced on the feed plate, the pressure is released. Flash vaporization occurs and the majority of the lighter components begin their ascent from deck to deck to the top of the tower. A small percentage of the heavier components at the same time evolves as a vapor and is carried up the tower progressively from tray to tray in diminishing amount.

The heavy components drop downward by steps to the base of the column. In the stabilizing process it is necessary to add heat at some points and at others to remove it. Because heat must be added at the bottom to obtain a definite vapor-pressure product, a reboiler or kettle is provided for that purpose. The reboiler is directly connected at the bottom with the liquid reservoir of the column proper and on the topside it is also connected with the column by means of a vapor line that enters between the first and second trays. The reboiler consists essentially of a shell of tubular shape in which is installed a large bundle of tubes. The liquid falling to the base of the column builds-up a continuously equivalent level in both vessels. Steam is used in the tube bundle as a source of heat and the amount is controlled to give a uniform tower-base temperature. The vapor space above the tube bundle should be sufficiently large to provide ease of evolution of the vapors from the heated gasoline. These vapors will pass through the vapor connection mentioned, to reenter the tower. The finished gasoline will be drawn from the bottom of the reboiler by means of a liquid-level control, passed through the heat exchangers, and from the cooling tower will go to storage.

Good fractionation is obtainable only by means of intimate contact of the continuously upgoing stream of vapor with the constantly downflowing stream of liquid. Each deck receives its vapors from the tray below and its liquid from the overflow of the tray above. As the top tray receives no overflow of liquid from an overlying tray it is necessary to provide liquid at this point from an external source. Reflux, or condensate from the overhead vapors, is pumped back at a constant rate to the top tray. Sufficient heat is extracted by governing the amount of reflux to permit the discarded components, generally propane and a portion of the butane, to exist at column pressure as a liquid,

The vapors rising from the tray below are slightly hotter than the liquid on the tray above. As they are saturated, i.e., are at the condensation point, any slight reduction in temperature will cause condensation of the heavier components. When coming in contact with the cooler liquid on the tray above the heavier components of the upgoing vapor condense. The liquid on the tray is already at its boiling point, so upon receipt of the heat of vaporization of those components that have returned to the liquid state, there occurs an evolution of the more volatile components in vapor form.

The vapors from plate 28, for instance, are partially condensed on plate 29. As this condensation takes place, the tray liquid level on plate 29 is raised. Because the rising vapor stream is constant, there is a continuous condensation and a resulting constant overflow of liquid through the downspout to plate 28. This overflow is at its boiling point and as it flows out on plate 28 it immediately vaporizes and rises again to plate 29. Again it condenses, overflows, and vaporizes, this process recurring again and again in the same order. The vapor from plate 29 rises to the top plate, plate 30, where the heavier components are condensed to return to plate 29 to revaporize, etc. The reflux introduced on the top plate takes the heat of vaporization from the condensing components, vaporizes, and passes out overhead to be cooled and from thence to the reflux accumulator for return to the column again as reflux. There is a certain amount of overhead new material that is continuously evolving from the raw feed to the column. This "make" or surplus reflux is in most cases further processed.

An endless cycle and recycle of condensation, overflow, and vaporization occurs on every plate in the tower. These continuous and progressive partial condensations and vaporizations through the addition and extraction of heat result in a liquid that is less volatile flowing down the column and a vapor stream moving up that progressively becomes more volatile.

Reflux Ratio

The reflux ratio is generally expressed in terms of reflux/waste. That is, if the discarded gas from the column represents 15,000 gal. and if the reflux returned amounts to 75,000 gal., the reflux ratio is 75,000/15,000, or 5 to 1. The waste is measured as a vapor and the reflux as a liquid. The waste must be converted, therefore, to a gallon basis before the ratio is computed.

The higher the reflux ratio, generally the higher the column efficiency that will be attained. This increased efficency results from a greater yield due to closer separation. There is an overload point, however, beyond which an increased ratio will be detrimental.

The reflux should be returned to the column on the top plate and it should be of as near the same composition as the overhead product as possible.

There are two methods used to provide reflux to the top tray, (1) by means of a partial condenser set directly on the flanged opening on top of the column proper, and (2) by pumping the reflux from an accumulator tank, which catches the overhead product as it comes from the cooling coils. When the overhead surplus is later processed in some manner, the reflux condenser must be operated at as near its total condensing capacity as possible. The latter method is by far the more favored, in large part because of its flexibility in operation.

Top and Bottom Temperatures

The top temperature of the column is closely coördinated with reflux ratio in that the efficiency of separation, that is, the amount of heavier components that reach the top plate, is dependent on the top temperature, which in turn is dependent on the amount of reflux returned to the column.

For a designated constant operating pressure and base temperature, the top tray temperature will be established for a given composition so that no marketable gasoline will leave as a vapor. If the pressure and bottom temperature have remained constant and yet the top temperature has increased several degrees, it is a safe assumption that marketable components have reached the tray.

The top temperature is dependent on the bottom temperature in that all material entering the column must leave it at either the top or bottom. The bottom temperature is the factor determining the volume of the portion that will leave the kettle as finished product; the top temperature determines which components will leave overhead.

The bottom temperature must be set to obtain a gasoline with a vapor pressure, at column pressure and bottom temperature, equivalent to that of the desired finished product at 100°F. without the excessive use of reflux.

In order to make adjustment for too high or too low vapor-pressure gasoline it is necessary to increase or decrease the bottom temperature enough to permit vaporization or cause condensation

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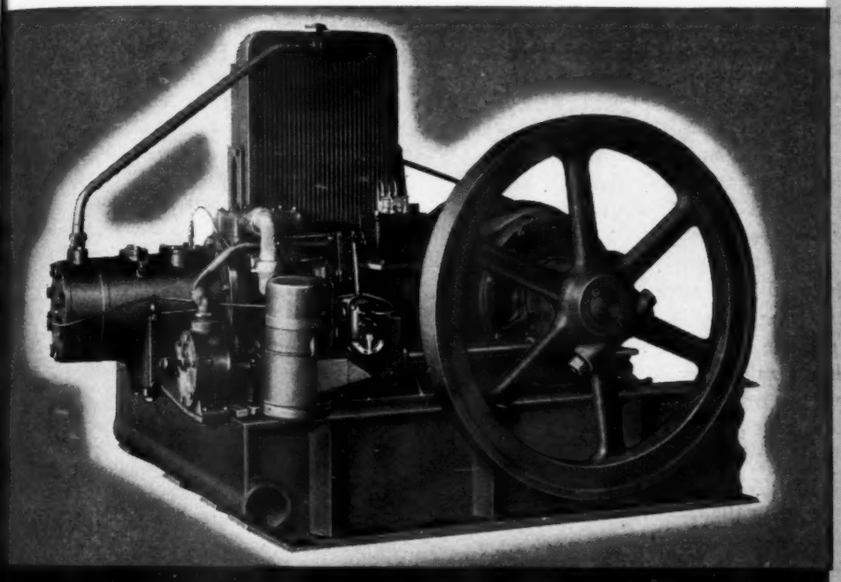

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of enough of the lighter components to obtain the desired result.

It has been found in many plant operations that when the unit is operating and has been properly balanced, an increase or decrease of 2°F. in bottom temperature will decrease or increase the vapor pressure of the finished product by approximately 1 lb. Reid vapor pressure.

Tower Pressure

After the determination of the lowest practicable operating top temperature, the approximate column operating pressure can be selected from a vapor-pressure chart. The top temperature at which it will be expedient to operate will determine the pressure at which the system must be operated; the pressure must be such that the overhead product may exist as a liquid at the top tray temperature.

A constant system pressure is very important because as little as a 4-lb. pressure change has been found to raise or lower the vapor pressure of the finished product as much as 1 lb. Reid vapor pressure. The degree of susceptibility of vapor pressure change to changes in system pressure is of course variable.

When the top temperature and bottom temperature have been established, the pressure of the system is the determining agent as to the quality of the finished gasoline. For that reason, the pressure must be kept constant in order that the maximum quantity of marketable gasoline may be obtained.

Stabilization Efficiency

Factors that enter into the efficient stabilization of the raw gasoline are, in addition to the tower adjustments outlined, mainly instrumentation problems.

The rate of feed should be constant, as a varying volume will create a continuous surge in the vaporization and condensation operations and tend to keep the column out of balance. The quality of the feed should also be kept as constant as possible. In order to provide this constant rate and quality of feed, a flow controller-recorder is sometimes essential as is a "surge" or make tank with sufficient capacity to permit any required change to occur over a long period of time. As the gas load on the absorbers and the oil-gas ratio are more or less constant in the majority of natural gasoline plants, the rate and quality of the raw make feed to the column are as a rule quite constant. Any atmospheric change affecting either the quantity of raw make or composition is usually so gradual that the change is spread over such a period of time as to be negligible. A small vertical surge drum or accumulator is now used in many installations instead of the large capacity tank of earlier plants and a liquid-level control actuates the steam-throttling valve to the stabilizer charge pump. The flow or charging rate may not be constantly uniform, but the slight inconsistency of feeding rate has not been found to be of serious consequence.

The base, or kettle temperature, is governed by a throttling valve operated by a controller-recorder. This instrument should be very sensitive to temperature change and give a high degree of control as it has been found that as little as one degree variation in reboiler temperature will affect the finished product by as much as one-half of one percent in volume. Steady control is here as important as accuracy.

The feed inlet temperature will be affected materially if the flow of the hot gasoline from the kettle through the heat exchangers is by surge flow rather than uniform and continuous. A uniform heat input at the feed tray is advantageous in keeping a well-balanced tower. Slugging of the finished product from the reboiler will also upset the uniformity of the kettle temperature. It is imperative, therefore, that a smooth-acting liquid-level control be placed on the reboiler to insure a uniform rate of discharge.

There are two major methods of control used in top-temperature maintenance. In a number of the older plants and in a few of the newer ones, the top-temperature controller is still used. In the last few years, however, the inclination has been to install a top-temperature indicator or recorder and to use either a flow-controller to measure and hold constant the quantity of reflux or a hand control for pump speed. A reflux control that is favored by many engineers today maintains the reflux in step automatically with the raw charge so that although the charge rate may vary, the ratio will remain constant. There are a number of installations, however, that have no provision for automatic ratio control; in lieu thereof, a hand throttling of the reflux pump is used for the approximate attainment of an overhead with a definite composition. Those using reflux ratio control regard the fluctuation of the top temperature of minor or little importance so long as the reflux ratio is constant and the top temperature is permitted to vary at will. Those using the hand-control system base their operation pretty much on the same theory so far as actual plant results in operation are concerned.

The amount of overhead required as condensate is the determining factor in the placement of the back-pressure regulators. When a maximum amount of overhead is required as condensate and the surplus above that needed for reflux is to be charged to the propane-butane columns or to some other unit, two back-pressure regulators are often installed. One on the vapor line from the stabilizer will hold a definite constant system pressure, the other on the discard gas from the reflux accumulator will be set for approximately 20 lb. less than the system control. The non-condensable gases will be relieved through the latter regulator to the residue side of the gas system. Any fluctuation that might occur in the system due to variations in atmospheric conditions when only one regulator is used on the downstream side of the accumulator will, by "double-valving", be held in the reflux drum itself.

There are several other arrangements of back-pressure valves in general use. A variety of installations are used in the control of reflux condensation to obtain the exact amount needed to hold a level of liquid in the reflux accumulator, the uncondensed portion of the condensable overhead going out with the non-condensable gases from the reflux accumulator through a back-pressure valve.

The back-pressure regulator should be such that smooth and uniform operation can be maintained. Changes in pressure can upset the column balance just as effectively as can variation in column-base temperature. The high and low variation in pressure should not be more than 1 lb.

No more controls than are essential should be installed. All control points are subject to a variation of approaches so far as installation is concerned. It will be found, however, that the simplest approach is the best. The tendency toward overcontrol is perhaps more advantageous than trying to operate efficiently with too few controls. And in conclusion, selection of controls having capacity to fit the job is of paramount importance.

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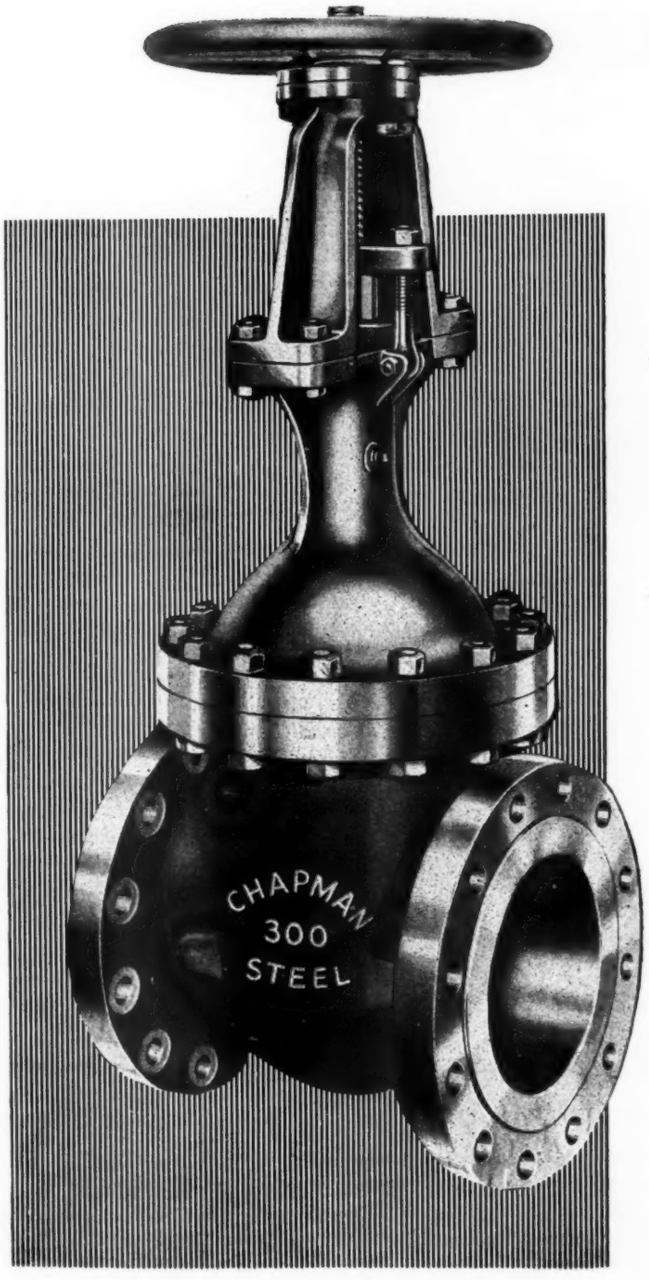

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Air and Fuel-Gas Cleaners Installed on Engine Driving Geared-Power

By J. C. ALBRIGHT

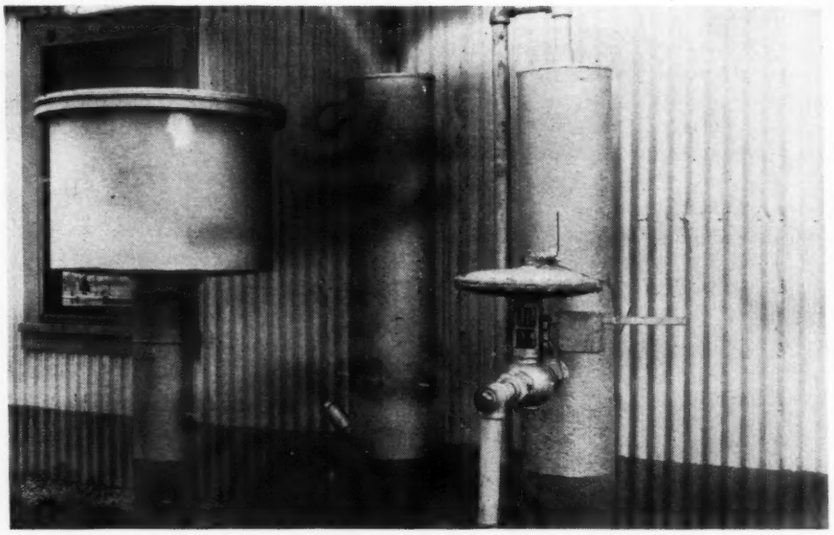
TO provide clean air and fuel to the engine driving a geared-power recently installed in the Boucher pool, Jackson County, Oklahoma, cleaning devices have been installed. High winds and sandy soil result in a dust-laden atmosphere, making the removal of abrasive material from the air to the engine necessary. The gas from the wells, used as fuel, contains small particles of scale and foreign matter that should be removed before the fuel enters the engine.

Clean air to the engine is obtained by means of an oil-bath air cleaner installed on the air-intake pipe of the engine.

The device for cleaning and washing the fuel gas, designed and fabricated on the lease, is novel and merits description.

The device consists of two tanks—a cleaner and a washer—each fabricated of 10-in. pipe about 5 ft. in length, closed at both ends by a flat head, welded in place. Connections on the washer are placed in the center of the upper head and near the base in the side of the unit. These connections are used for gas piping; the lower for the inlet, and the upper for the pipe leading to the mixing valve on the gas engine.

A third connection is welded at an angle of 45 deg., about 18 in. from the base, using a nipple for this purpose, having a collar and plug made-up to close the opening. An oil having a gravity of about 36 deg. A.P.I., similar in boiling range to an ordinary gas oil, is poured into the vessel through the angular connection until the fluid level is about 18 in. from the bottom head. The fuel gas from the cleaner enters the vessel through the bottom connection, and flows upward through the body of oil. Contact with the oil removes the foreign matter from the gas; the abrasive material thus removed settles to the base instead of passing into the mixing valve of the engine.



Equipment installed on air intake and fuel system of Gulf Oil Corporation's geared-power unit in Boucher pool, Oklahoma

The cleaner (of the dry-type) is installed in the fuel line, upstream from the washer, to remove heavy particles that drop-out as the velocity of gas decreases upon entering the larger vessel. The pressure is reduced by a field regulator installed in a horizontal position on the inlet pipe to the dry-cleaner. Gas from the dry-cleaner goes out through a connection in the top of the vessel and then enters the oil-wash vessel.

New Thread Standards, Two Supplements, Published by A.P.I. Production Division

NEW tentative standards covering specifications for the inspection of threads on oil-country tubular goods, and supplements to standards on the rating of speed reducers for pumping machines and specifications for standard rigs and derricks have been published by committees of the American Petroleum Institute's Division of Production, Dallas, Texas, C. A. Young, secretary of the division, announces.

The thread-inspection specifications, published for the first time, supplement A.P.I. standards covering pipe and threads in fittings, in that they govern the instruments and methods to be used in inspecting all thread dimensions specified in those standards (A.P.I. Standards No. 5-A, 5-F, and 5-L). Sections of the 34-page booklet discuss: contact points of instruments; dial gauges; visual inspection; marking threads for measurements; taper; lead; height of thread; angle; thread form, and inspection and rejection. Copies are for sale at 50 cents each.

Supplement No. 1 to the 3rd edition of Standards No. 11-E: "Rating of Speed Reducers for Pumping Machines," effects changes in nomenclature and in the nameplate for speed reducers. Supplement No. 3 to the 9th edition of Standards No. 4: "Specifications for Standard Rigs and Derricks," includes changes given in the two previous supplements, and adds amendments adopted at the A.P.I. Midyear Meeting. The newest additions cover: safe load capacity; support of working platform; minimum number of bolts; nominal safe load capacity of gin pole; loads and forces on gin pole; endless-belt lengths; shaft spacing for belt drives, and shearing stress in webs of silicon beams.

Methods of Supercharging Diesel Engines

Supercharging air to cylinders employed as means of obtaining increased horsepower output or of offsetting power losses resulting from rarefied atmospheres, high summer temperatures, and other abnormal conditions

By ORVILLE ADAMS

THE theory of supercharging the internal-combustion engine has received much study from both the academic and the practical man. The academic man has found the subject a most intriguing and scholarly problem. The practical man has found it offers a means of increasing the horsepower output per unit weight of engine, and a means of maintaining the normal horsepower output, which is reduced by certain adverse conditions such as prevail when operating at high altitude.

The principal result of supercharging is to deliver more air to the cylinder per working stroke, which enables the engine to burn more fuel per stroke, thus producing a higher mean effective pressure and greater horsepower output. It is important to note that supercharging does not appreciably increase the maximum firing pressure within the cylinder. Supercharging does prolong the combustion period, and hence develops a higher mean effective pressure. If the degree of supercharging should produce appreciable higher firing pressures, a redesign of the engine would be necessary to strengthen the parts affected. The result would be a heavier engine, thus offsetting greatly the benefits of supercharging.

Theory of Supercharging

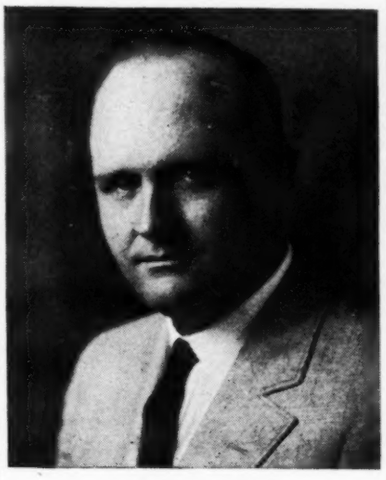
The weight of air drawn or forced into the cylinder per piston stroke is theoretically:

$$w = \frac{p_1 v_s}{R t_1}$$

where

w = weight of air in lb.
p_1 = absolute pressure of the air in the cylinder, in lb./sq. in.
v_s = volume swept by the piston
t_1 = absolute temperature of the air in the cylinder
R = constant for air, 53.34.

This is merely a modification of the general formula to meet the special conditions within the cylinder, as these conditions are not the same as those existing in the ambient atmosphere at the engine. Usually they are more adverse insofar as the engine is concerned.



ORVILLE ADAMS

was educated at Kentucky State College and served in the technical branch of the army during the World War—After his discharge from the service he was for ten years sales engineer for Diesel engine manufacturers—Since 1930 he has devoted his time largely to the writing of text books and articles for leading technical journals—Is the author of authoritative text books on the Diesel engine that are widely used in technical schools, and at present is preparing a text on Diesel engine thermodynamics for college use—Is also engaged in research and investigation and the preparation of engineering reports on Diesel engine applications.

The reasons for these conditions should be noted. Pressure difference must exist to cause air to flow, and the air will flow from the higher toward the lower pressure. As the engine piston moves downward on its suction stroke, it tends to decrease the air pressure in the cylinder. Because "nature abhors a vacuum," and in order to fill the space vacated by the piston, air rushes in through the air-inlet system and past the air-inlet valve to fill this space above the piston in the cylinder.

It has been determined that the speed of the air through the valve port is roughly ten times the piston speed, and the pressure loss of the air due to such a high velocity prevents the air in the cylinder reaching normal atmospheric pressure. This pressure drop is low for slow-speed engines having smooth manifolds and large valve areas, whereas it may be high for high-speed engines having long or obstructed air-inlet systems. Although the pressure in two-stroke-cycle engine cylinders is not reduced below atmospheric, the quantity of fresh air introduced may be less than the calculated piston sweep.

The temperature of the air entering the engine is frequently greater than the standard conditions of 60°F. For this reason, air should be drawn from outside the building when possible. As the air enters the engine it is warmed by radiation from the various metal surfaces with which it comes in contact. In a 2-cycle engine, the crankcase, lower side of the piston, and the air passages become effective heating surfaces. In the 4-cycle engine, it is the valve ports and valves that radiate heat to the air. As the fresh air rushes into the cylinder it mixes with some of the hot residual gases that were not expelled on the exhaust stroke. The volume of such residual gases may be as low as 6 to 8 percent of the piston sweep volume for the 4-cycle engine, to as high as 30 to 40 percent of the piston sweep volume for the 2-cycle crankcase scavenging engines. In the 4-cycle engine, the residual gases may have a temperature of 600 to 750°F., whereas in the 2-cycle engine the gases will have temperatures of 400 to 450°F. It must be noted, also, that in the 4-cycle engine the air charge is in the cylinder for a fraction of a second before the compression stroke begins. As the air enters the cylinder it is warmed by direct contact with and radiation from the piston head, cylinder walls, and cylinder head. The similar heat transfer effect is much less pronounced in the 2-cycle engine, due to the shorter time that elapses between the introduction of the air and the overrunning of the ports by the piston, which is equivalent to closing the valves. The temperatures of the metal parts are not so great in the 2-cycle engine as in the 4-cycle engine.

(Continued on page 92)

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From an original drawing by Orison MacPherson

sures in addition to its own weight hanging in a well as deep as three miles.

"It is our responsibility to supply oil men with pipe that will enable them to carry on their amazing progress in petroleum production — pipe such as the A. P. I. grades, and J & L 'Blue Ribbon' Seamless. When this pipe you see here goes into service, each length of it will carry its J & L Controlled Quality pedigree marked right on it — even to the initials of the inspectors under whose vigilant, skilled eyes it must pass for final OK.

"Steel production at J & L is a partnership of science and skill, with research piloting the way to new steels — new ways by which this versatile metal may better serve mankind — at lower costs."

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OIL

Petroleum brings world's news to us through newsprint ink, a mixture of petroleum oil with carbon black, by-product of natural gas.

Sea-going oil wells, two miles deep, are drilled from barges in 30 feet of water, in Texas and Louisiana. In California, Texas, and Venezuela, derricks are rigged over the ocean, the Gulf of Mexico, and many lakes. With the new practice of "directional drilling," operators set up derricks on land and reach out for oil beneath water or other natural barriers. Holes have been "directed" a lateral distance of 3,200 feet in 5,000 feet of drilling.

You walk on petroleum in the jute backing of carpeting and rugs treated with water-oil mixtures during processing.

Home-made earthquakes, created by deep shot-holes and dynamite, are a modern seismographic method of finding oil reserves by recording reflections of the shot vibrations from rock structures down 20,000 or 25,000 feet. The simple means used by the early oil pioneers to "locate" wells—by "doodle bugs" (valueless pseudo-scientific gadgets), or peach twig divining rods—have given way to modern science. Today geophysical prospecting is the greatest single factor in finding deep oil reserves. Petroleum geologists predict new advancements in prospecting methods will discover new supplies.

$300,000 for three miles was the cost of the world's deepest well drilled in California. Average wells cost from $40,000 to $100,000—and many are "dry holes."

Tomorrow's Wildcat starts at today's depth record, oil men say. Four-mile depths await only location of sufficient reserves and demonstration such costly wells will pay.

Oil big steel user. More than 1,250,000 gross tons of steel products were bought by the oil industry in one year (1937)—which provided employment enough to keep about 40,000 steel workers on the job 52 full weeks. Other industries share in oil's $1,000,000,000 a year purchases of equipment, supplies, services—tin cans to shovels, sulphuric acid to railroad cars, paper clips to ocean-going tankers.

By-products from petroleum include resins, solvents, and alcohols.

A million safe man-hours is no longer a rarity in operation of oil and gas leases. Safety has been improved 85% in 20 years.

How old is oil? Before the birth of Christ, townsfolk of Agrigentum, Sicily, burned petroleum in make-shift lamps. Egyptian mummies were preserved in asphalt from a spring on the Island of Zante. Plutarch describes a lake of blazing petroleum near Ecbatana, in Persia. An oil fountain in the Ionian Islands, west of Greece, has been bubbling for 20 centuries.

(Continued from page 89)

It is to be noted, then, that the temperature of the air and gas in the cylinder at the beginning of the compression stroke is greater than the atmospheric temperature. Certain factors will cause this temperature rise to vary, but for our purpose it is sufficient to indicate that it may be 40° to 120°F. above the temperature of the air that originally entered the air-inlet system. The effect may be and usually is appreciable. To obtain an idea of what the effect of these conditions is, compare the weights of air drawn or forced into a cylinder of 1 cu. ft. volume, a cylinder 12 in. by 15.28 in. for example.

The equation for the weight of the air drawn into the cylinder is:

$$w = \frac{pv}{Rt}$$

where:

w = weight of air in lb.
p = absolute pressure of the air
v = volume of the air
t = absolute temperature of the air
R = constant for air, 53.34.

(1) Assume standard rating conditions, as follows:

t = 60°F., or 520° abs.
p = 29.92 in. Hg., or (14.696 × 144) lb./sq. ft.
v = 1 cu. ft.
then:

$$w = \frac{14.696 \times 144 \times 1}{53.34 \times 520}$$

w = 0.07630 lb.

These are standard conditions usually assumed; but

(2) Assume summer weather atmospheric conditions, as follows:

t = 90°F., or 550° abs.
p = 29 in. Hg., or (14.24 × 144 lb./sq. ft.
v = 1 cu. ft.
then:

$$w = \frac{14.24 \times 144 \times 1}{53.34 \times 550}$$

w = 0.06990 lb.

(3) Assuming the same summer conditions, but allowing 0.5 lb. per sq. in. drop in pressure due to friction of air entering the cylinder, and a heating effect that raises the air temperature 50°F. above the outside air, or:

t = (90 + 50) = 140°F., or 600° abs.
p = [(14.25 — 0.5) × 144] lb./sq. ft.
v = 1 cu. ft.
then:

$$w = \frac{13.75 \times 144 \times 1}{53.34 \times 600}$$

w = 0.06187 lb.

(4) Assume a winter condition of 0°F., but allow the same 0.5-lb. pressure drop and 50°F. heating effect as in example (3) above, or:

t = 0°F. + 50° F., or 510° abs.
p = (13.75 × 144) lb./sq. ft.
v = 1 cu. ft.

$$w = \frac{13.75 \times 144 \times 1}{53.34 \times 510}$$

w = 0.07279 lb.

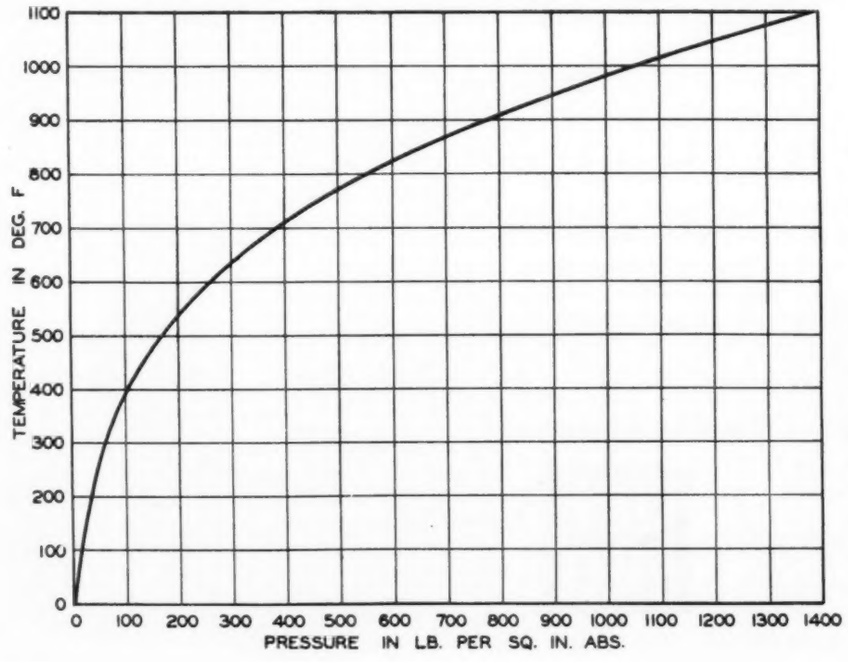
These differences in the weights of air drawn into the cylinder show why it is necessary to allow the air to reach the engine as cool and as near atmospheric pressure as possible. The summer conditions given in Example (2) are typical of many mid-western areas, therefore, the pressure drop and the heating effect assumed in (1) and (3) are reasonable. Between the conditions of (1) and those of (3), however, the air loss amounts to:

$$\frac{0.07630 - 0.06187}{0.07630} = \frac{0.01448}{0.07630}$$

= 19 percent

Thus there is a 19 percent loss under average summer conditions. The loss would have been considerably greater in the high hot areas of the west, for there the air is dry and the altitude greater than average, the only remedy for which is supercharging. Consider, then, the advantage of taking in the cold outside air in the winter time as in (4). The cold air does much to overcome the weight loss due to friction pressure drop. This explains why engineers undertake to attain atmospheric conditions within the cylinder. Good supercharging aims to raise the inlet air pressure above that of the atmosphere to a value of 16 to 20 lb. abs. instead of leaving it at approximately 14 lb.

Fig. 1. Curve showing temperature rise of the air caused by compression



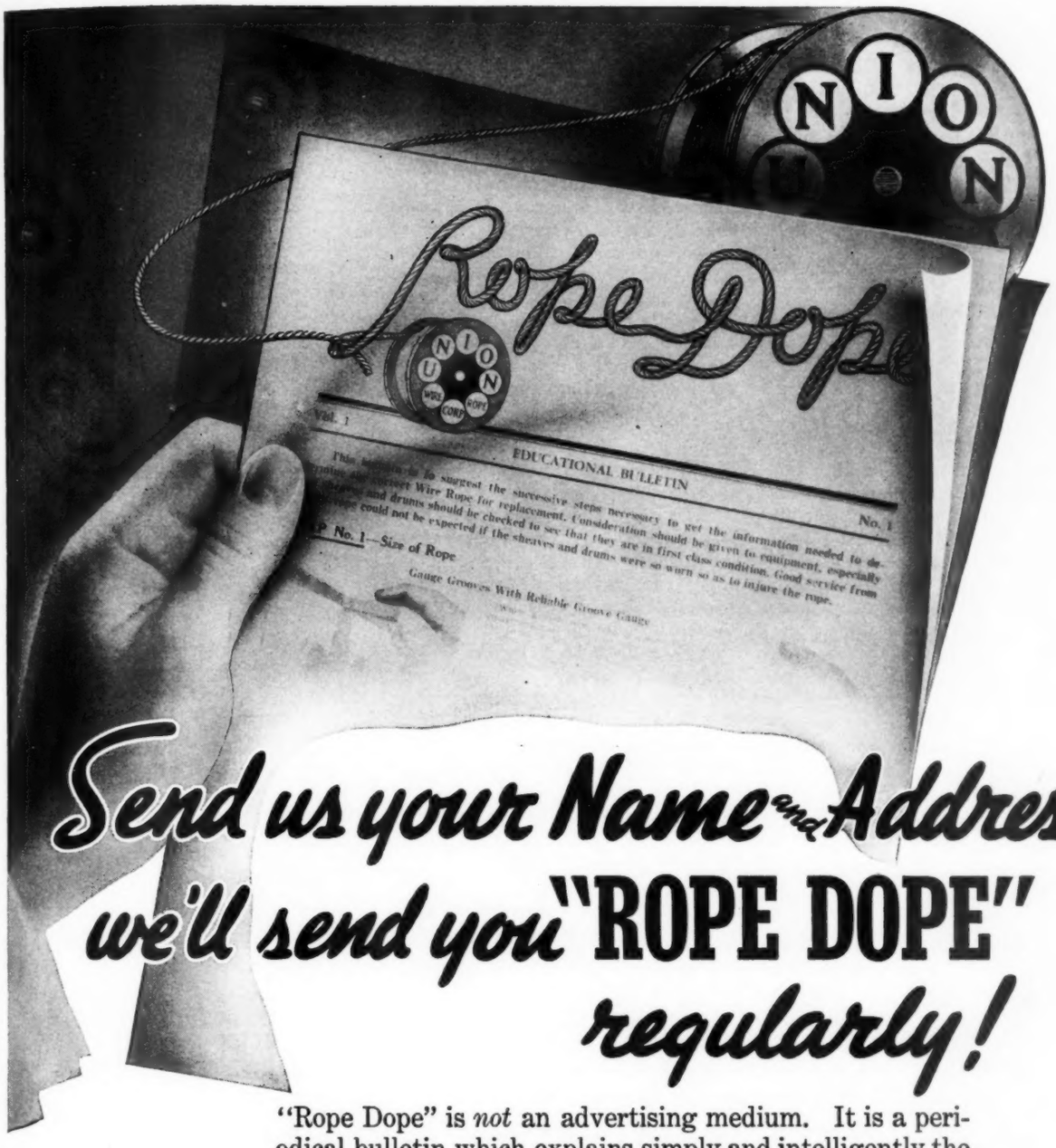
Methods of Supercharging

There are many ways to supercharge:

(1) By utilizing the inertia of the mass of gases. This is accomplished (a) by timing of the valves; (b) by using out-of-phase pistons in an opposed-piston engine; (c) by using a long, smooth inlet-air pipe, and (d) by the use of auxiliary valves.

(2) By mechanical compression of the inlet air, by means of (a) rotary blowers of the positive displacement type driven from the engine by gears, chains, or belts, or separately driven; (b) centrifugal type blowers driven by any of the methods of (a) or driven by an exhaust turbine; (c) reciprocating compressors or air pumps separately driven, or as a part of the engine as the scavenging pump on two-stroke-cycle engines, and (d) using the underside of the piston as a compressor on cross-head engines.

The methods outlined are not appli-



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cable to both two-stroke and four-stroke engines, and in many cases a combination of a method from group 1 and a method from group 2, is used. The four-stroke-cycle engine having regular poppet valves may be supercharged by mechanical means to some degree without changing the valve timing. In most cases, however, it is desirable to change the timing of the valves in order to obtain the optimum of supercharging. It is not possible to supercharge effectively a port-scavenging two-stroke-cycle engine without making provisions to trap the air charge. As the inlet ports close ahead of the exhaust ports, it is obvious that this type of engine must be modified before it can be supercharged. If, on the other hand, the two-stroke-cycle engine is equipped with overhead exhaust valves or is of the opposed-piston type, (either has a uniflow scavenging action), the valve timing or piston phase may be adjusted to trap the scavenging air at higher than atmospheric pressure. The common systems may therefore be grouped according to the application to engine cycles.

(1) Two-stroke cycles:

(a) By using any mechanical blower or air pump in an engine having an overhead exhaust valve, and changing the valve timing so as to permit the exhaust valve to close while air is still entering the cylinder; (b) by using any mechanical blower or air pump, and an auxiliary supercharging valve that admits air after the ports are closed, and (c) by using any mechanical blower or air pump in an opposed-piston engine having the pistons out-of-phase. Here the exhaust piston opens its port before the inlet piston and closes them before the scavenging ports are closed by the inlet piston.

(2) Four-stroke-cycle engines:

(a) By charging by means of changing valve timing to produce an inertia supercharging effect; (b) by using a smooth, straight inlet pipe of the proper diameter and length to produce an inertia supercharging effect, and (c) by using any mechanical blower or air pump to maintain a pressure on the intake manifold. For best results with this system it may be desirable to change the valve timing and eliminate the overlap. The details and advantages of each method as outlined above have been discussed in the literature on this subject, and the necessary theory on air compressing and air flow should be studied in order to gain a better understanding of the practical difficulties involved.

The question may arise regarding the effect of lower air densities upon the temperature of the air charge at the end of compression. Inasmuch as a Diesel engine has no ignition apparatus such as spark plugs, it depends entirely for ignition of its fuel upon the temperature rise of the air charge caused by compression (see Fig. 1). As the temperature caused by compression is a function of the pressure ratio rather than the actual pressures, the temperature conditions are not affected at all.

The compression in a Diesel engine follows the adiabatic law:

$$R_t = R_v^{0.4} = R_p^{0.286}$$

where:

R_t = ratio of absolute temperature of the air before and after compression

R_v = ratio of volume of the air before and after compression

R_p = ratio of absolute pressure of the air before and after compression

For example, assume an engine having a compression pressure of 500 lb. gauge, or 514.7 lb. abs. at sea level, or:

$$R_p = \frac{514.7}{14.7} \qquad 35 =$$

then:

$$R_t = R_p^{0.286} = 35^{0.286} = 2.76$$

This is the factor to be used in calculating the temperature of the air after compression. Thus, if the temperature at the beginning of compression is equal to atmospheric, or 60°F. plus suction heating of about 100°F., the absolute temperature at the beginning of compression will be:

$$60 + 100 + 460 = 620°\text{F.(abs.)}$$

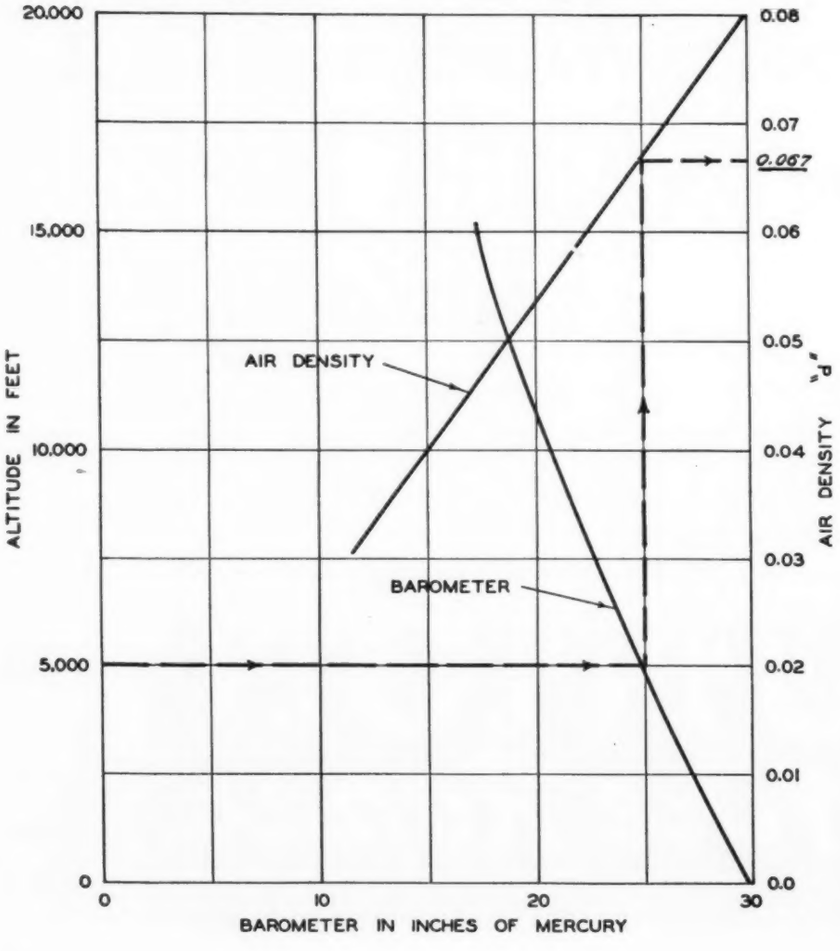
and the temperature, T_2, at the end of compression will be:

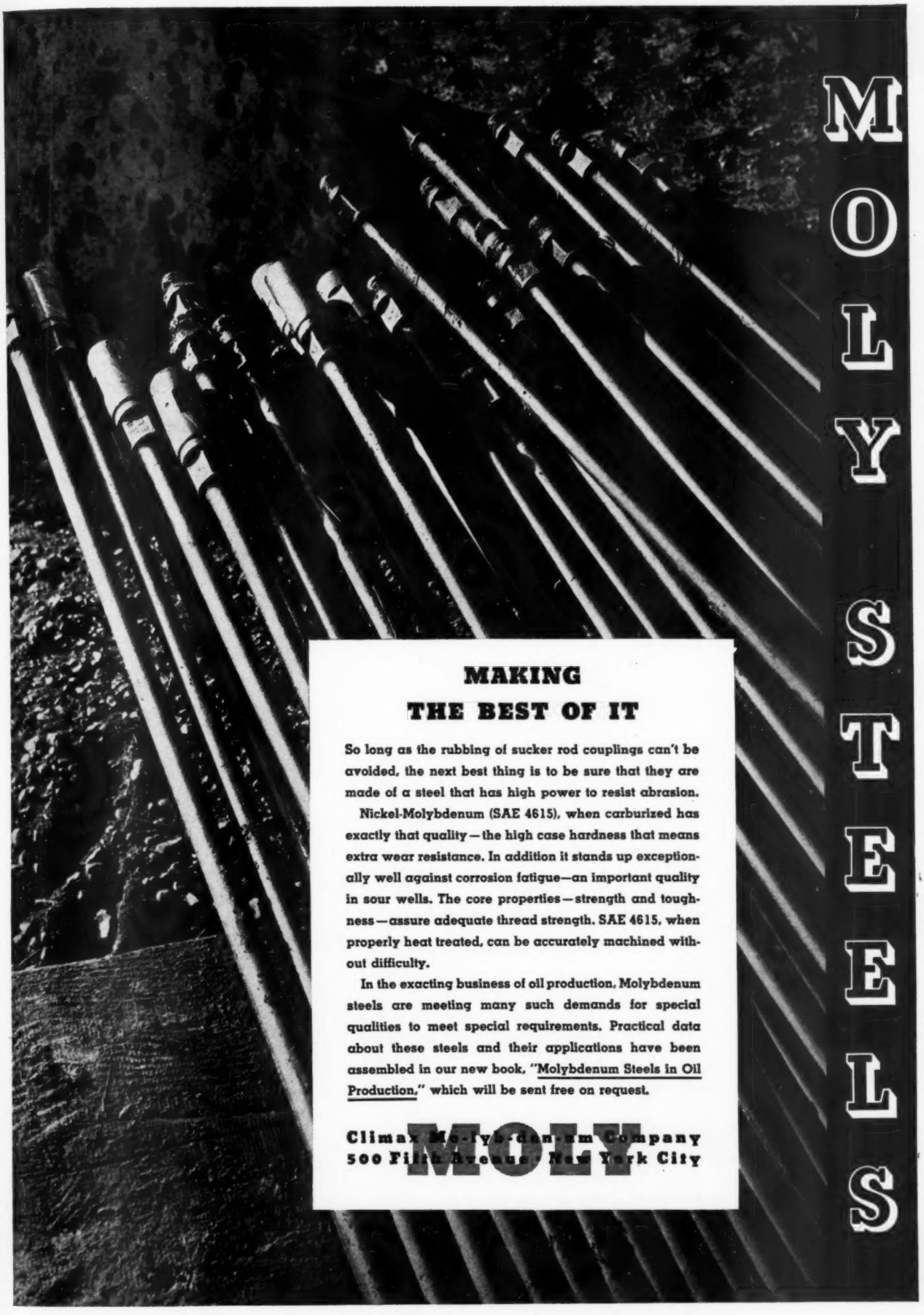
$$T_2 = 620 \times R_t = 620 \times 2.76$$

$$T_2 = 1710°\text{F.(abs.)}, \text{ or } 1250°\text{F.}$$

If the same engine is at 5000 ft. altitude, with the compression volume ratio R_v remaining the same, the temperature ratio will still be 2.76, regardless of the pressure at the beginning of compression, and, therefore, the engine, so far as assurance of satisfactory ignition is concerned, will operate as at sea level.

Fig. 2. Relation between air density and altitude





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A cubic foot of air at sea level and 32°F. weighs 0.0807 lb., and at 10,000 ft. altitude and the same temperature, weighs 0.056, or only 69.4 percent of that volume of air at sea level.

The adiabatic equation for obtaining the temperature at the end of compression, is:

$$T_2/T_1 = (P_2/P_1)^{(n-1)/n}$$

$$\text{or, } P_2 = P_1 \sqrt[\frac{n-1}{n}]{\frac{T_2}{T_1}}$$

where, T_1 = abs. temp. before compression

T_2 = abs. temp. after compression

P_1 = abs. pressure before compression

P_2 = abs. pressure after compression

$n = 1.3$

$(n-1)/n = 0.23$

now assume:

$T_1 = 530°F.$

and $P_1 = 12.9$ lb./sq. in.

and also assume various values for T_2 from 760°F. to 1560°F.,

When $T_2 = 760°F.$

$$P_2 = P_1 \sqrt[0.23]{\frac{T_2}{T_1}}$$

$$P_2 = 12.9 \sqrt[0.23]{\frac{760}{530}}$$

$P_2 = 62$ lb./sq. in. (abs.)

Similarly:

When $T_2 = 960°F.$
$P_2 = 171$ lb./sq. in.

When $T_2 = 1160°F.$
$P_2 = 389$ lb./sq. in.

When $T_2 = 1260°F.$
$P_2 = 557$ lb./sq. in.

When $T_2 = 1360°F.$
$P_2 = 776$ lb./sq. in.

When $T_2 = 1460°F.$
$P_2 = 1060$ lb./sq. in.

When $T_2 = 1560°F.$
$P_2 = 1410$ lb./sq. in.

As the percentage of air and oxygen in air is constant regardless of altitude, and fuel must have oxygen in order to burn, if the density of the air is reduced by 20 percent, the amount of fuel that can be burned is reduced also 20 percent per unit volume, as is the power output of the engine. The relationship of air density to altitude is shown in Fig. 2. For example, at an altitude of 5000 ft. and barometer reading 25 in. the air density is approximately 0.067. If the amount of air, and hence the amount of oxygen, is reduced due to a decrease in density, the amount of oil that can be burned per cycle will be reduced in direct proportion, and the available power will again be less in ratio of the air density at operating conditions to that at sea level.

Analyses Made of Crude Oils from Producing Fields of Arkansas

ANALYSES of 45 samples of crude oil, obtained from 25 fields in six counties of Arkansas, are given in a report issued by the U. S. Bureau of Mines in coöperation with the Arkansas Geological Survey. The report contains general information in regard to oil fields in Arkansas, which are listed in order of discovery with tabulated data on structure, means of discovery, and names of producing formations. The samples analyzed represent crude oils from producing strata of Upper and Lower Cretaceous ages and of the Smackover formation of earlier age. A brief summary of each field is given together with figures on production and production acreage.

Study of the Arkansas fields shows that 97 percent of the production to date has come from Upper Cretaceous formations. Deeper drilling since 1936 has resulted in new fields whose producing formations are of older age. Most of these discoveries are due to geophysical prospecting.

Of the crude oil samples shown, 8 are considered paraffin in base; 4 are paraffin-intermediate or close to the paraffin border line; 20 are intermediate in character, of which 15 are normal except for high sulphur contents, heavy residuums, and high carbon residues; 9 are in the naphthene-intermediate class and have sulphur content of approximately 2 percent or greater; and 4 items are of naphthene base, heavy viscous crude oils with high sulphur content, resembling liquid asphalts.

The most predominant characteristic of these 45 Arkansas crude oils is their high content of sulphur; 35 samples have a sulphur content of 0.7 percent or more, and average for all is 1.51 percent. An arbitrary classification into four groups according to percent of sulphur indicates that some of the physical and chemical properties change as sulphur content changes.

The producing fields of Arkansas may be divided into two groups: (1) The fields developed prior to 1936, whose production was derived almost entirely from formations of Upper Cretaceous age, and (2) the fields developed subsequently, whose production was derived from Lower Cretaceous or older formations. Of the 2830 wells that were producing on January 1, 1939, approximately 2552 are in the fields of earlier discovery, which include an aggregate area of 49,625 proved acres. In the later fields there are 278 wells in an aggregate area of about 4110 proved acres. Approximately 97 percent of all of the production in the first group of wells has been obtained from Upper Cretaceous formations. The Nacatoch sand of Upper Cretaceous age has produced about 47 percent, and the Ozan formation, also of Upper Cretaceous age, about 46 percent of all crude oil in the state. These fields were discovered partly by reason of some work on the surface geology, partly through general knowledge of the subsurface geology, and also because of "trend play." In most tests, drilling stopped at depths of 1500 to 4000 ft.

Since 1936, deeper drilling following geophysical exploration has resulted in the discovery of new producing fields in Miller, Columbia, Union, and Lafayette counties. The producing formations in these fields are all older than Upper Cretaceous age. The Rodessa field has been extended from Caddo Parish, Louisiana, into Miller County, Arkansas, and production is obtained from 5915 to 6292 ft. from the Glen Rose limestone in the Lower Cretaceous. Production was obtained in the Schuler field at depths ranging from 5551 to 5990 ft. from the Morgan zone of the Cotton Valley formation (Mesozoic), from 7500 to 7600 ft. from the Jones sand of the same formation, and from 7600 to 7675 ft. from the Reynolds zone of the upper Smackover formation, which also is assumed to be of Mesozoic age, although sometimes referred to as of Permian age.

The number of deep wells in the state has increased more than sixfold in the last two years. In 1936 only 60 wells in southern Arkansas were deeper than 4000 ft. In April, 1939, 384 wells had been drilled below that depth. The deepest well drilled in the state is the Tidewater Associated-Seaboard Oil Company Beene No. 1, completed December 8, 1938, in Columbia County at a total depth of 8332 ft. in the newly opened Atlanta district.

Copies of this paper, Report of Investigations 3486, "Survey of Crude Oils of Producing Fields of Arkansas," by O. C. Blade and George C. Branner, may be obtained free of charge from the U. S. Bureau of Mines, Washington, D. C.

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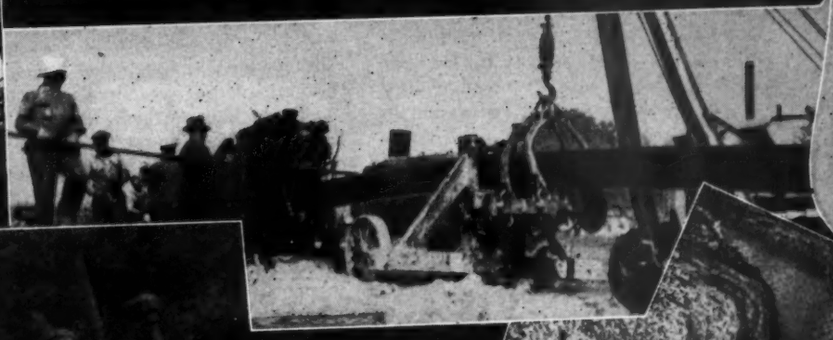

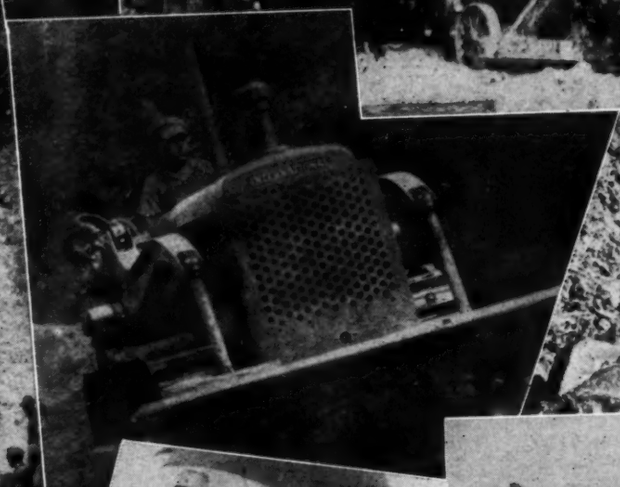

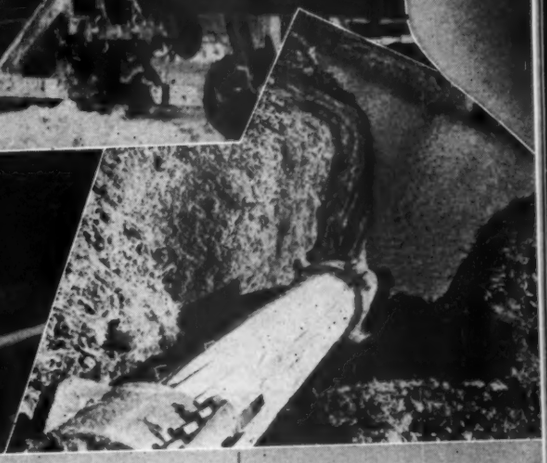

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Cathodic Protection of C

By

DONALD H. BOND

Electrolysis Engineer, The Texas Pipe Line Company

THE usual conception of cathodic protection, as visualized by members of the oil industry, is its application to the protection of buried pipe lines, because this method is now widely used for corrosion mitigation on such underground structures. Aside from this particular application there are many other structures that can be economically protected; the following discussion covers the successful application of cathodic protection to oil storage tank bottoms.

When considering the possibility of protecting any group of tank bottoms, there are several factors that must be considered. The first of these is the relatively large amount of surface area to be protected. This is more striking when the area of a standard tank bottom is compared to its equivalent in 6-in. pipe. Such a comparison is shown in the following table:

Tank capacity, bbl.	*Area of bottom, sq. ft.*	*Equivalent in linear ft. of 6-in. pipe*
37,500	7,100	4,095
55,000	10,300	5,940
80,000	10,700	6,171

From this comparison it may readily be seen that in a tank farm of average size, a considerable area of bottom-plate metal is exposed to the soil. In addition to this an appreciable amount of interconnecting pipe lines must be protected. Such concentration of metal area is advantageous, however, when cathodic protection is considered because the generating units and anodic distribution can be so arranged that the protective current may be more evenly and economically distributed to the surfaces to be protected.

At most tank farms power, in one form or another, is already available, so this problem is not so important as when trunk pipe lines are to be protected. If power is already being purchased at the tank farm, any energy consumed by the protection system can be classed as marginal and therefore figured at the lowest step in use on the prevailing rate schedule. Such power costs will usually be very economical.

When operating personnel are employed at the tank farm, the problem of maintaining the unit, or units, is greatly simplified. The operators can be given a few simple instructions concerning proper adjustments and care of the machinery, and make periodic and regular reports on the output of the units without interfering with their regular duties; consequently no extra operating labor cost will be incurred.

The important determination of the number of units to be used is, of course, a matter of engineering economics. To show the effect that a variation in the number of installed units has on the economics of an installation, the following example is given: Assume that 500 d-c. amp. are known to be required for complete protection of the tank bottoms and pipe lines in a specific tank farm. Also assume that a ground-bed circuit resistance of 0.20 ohm can be maintained and that the proposed system will operate with an overall efficiency of 50 percent. If one unit is used, it would need to be capable of delivering 500 amp. at 100 v. or a total of 50 kw. The estimated power required (P) for operating the unit is as follows:

$$P = \frac{100 \times 500}{0.50 \times 1000} = 100 \text{ kw.}$$

Now assume that five units can be used instead of the one, and that five separate ground beds can be installed whose resistances are maintained at 0.20 ohm each. This arrangement will require that each unit be capable of generating 100 amp. at 20 v. The total power required for operating the five units will then be:

$$P = \frac{5 \times 20 \times 100}{0.50 \times 1000} = 20 \text{ kw.}$$

Obviously an appreciable saving in power can be effected by increasing the number of units, provided the same ground-bed resistance is obtained for each of the individual grounds as for the one large one. Increasing the number of units will, of course, increase the installation cost, but to a certain point this may be more than offset by the saving in power. A happy medium must be reached and this can only be done after a careful comparison is made of the increased cost of adding more units versus the corresponding saving in power. The prevailing power rate will have a material bearing on this problem, especially where purchased power is used.

Another possible advantage is that by increasing the number of units, higher ground-bed resistance may be used without increasing the total power required. In the example given, five units having a ground resistance of 1.00 ohm each could be operated for the same power consumption required to operate the one large unit having a circuit resistance of 0.20 ohm. Even though no saving in power is realized, better current distribution will be provided, thereby reducing the amount of ground-bed cable required. By dividing the area to be protected into sections and providing a suitable generating unit for each, the anodes for each area will be relatively nearer the unit, thus resulting in a saving in cable as well as a reduction in the RI^2 loss in the conductors. Such a set-up may require additional transmission lines, but they

DONALD H. BOND

received a bachelor's degree in electrical engineering in 1930 from Louisiana State University—After graduation he was connected with New Orleans Public Service, Inc., as assistant testing engineer at their Market Street generating station—He later served as engineer on construction work until 1933, when he entered the employ of The Texas Pipe Line Company—After serving in various capacities with the company an assignment to electrolysis engineering was made in 1934, in which field of work he has devoted his entire time to the present.

Oil Storage Tank Bottoms

Forty-five 55,000-bbl. tanks in Gulf Coast tank farm are adequately protected by four 15-v., 100-amp., motor-generator units —three years' experience shows material reduction in cost of repairing steel bottoms

are less costly than the larger ground cables.

To determine the proper size cable to use in the d-c. circuit, a suggested approach is to determine the cost of power necessary to overcome the extra RI^2 loss in a smaller-sized conductor for a period of, say, 10 years and compare it to the additional cost of a larger cable. The most popular sizes in use vary from 00 to 0000. Reducing the size of the conductor within certain limits will have little noticeable effect on the potential of the protected structure to soil, but it will appreciably increase the power requirements.

Consideration should be given to the selection of proper generating equipment. If electrical power is available, either rectifiers or motor-generators may be used; both types are available for operating on either single- or three-phase service. Experience has indicated that there is virtually no difference in the overall efficiency of either type when power phase and operating conditions are identical. In the smaller sizes, the cost of each type is about equal, but as capacities approach 3 kw., the cost of rectifiers is slightly higher and increases appreciably at higher ratings. On the other hand, rectifiers require less attention and consequently less maintenance.

Recently a new plate-type rectifier has appeared on the market which, from all indications and claims, is superior to the usual pressure-disk type. The new unit consists of an oxide-coated plate having an alloy coating electroplated to the oxide film to serve as the positive connection. This produces a lifetime bond to the oxide, a condition that was difficult to obtain in the pressure-disk type. These new units will probably be less affected by climatic conditions, especially if coated with a suitable enamel.

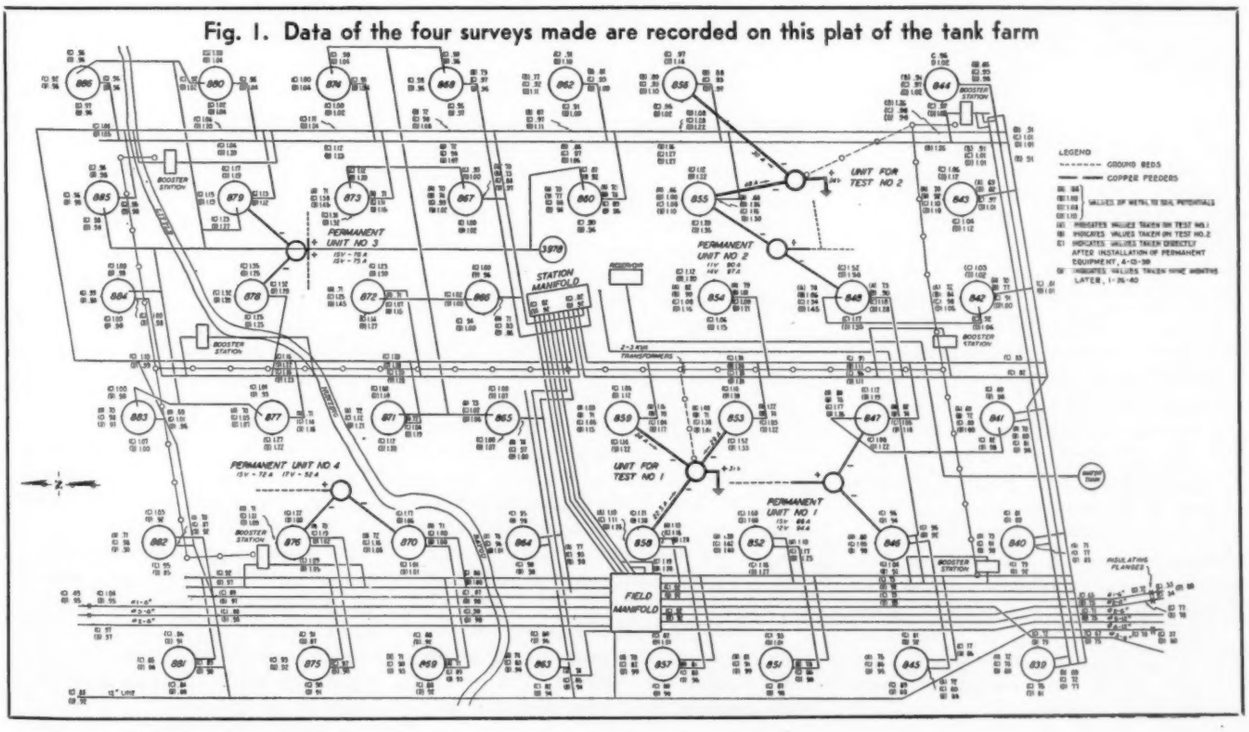
If a regular source of electrical power is not available, the particular power employed will necessarily determine the type of unit. Generators driven by gas, gasoline, or distillate engines may be considered. If pumping or similar engines are already in operation nearby and have enough excess horsepower, generators may be directly driven from these. Steam-turbine generators have great possibilities when steam is available. At least one installation of the latter type has been in successful operation for some time.

The efficacy of the cathodic method for protecting tank bottoms is fully substantiated by installations that have now been in operation for more than three years. The following data on one of the larger installations may be of considerable interest.

The tank farm in question, situated in the Texas Gulf Coast area, contains a total of 45 tanks of 55,000-bbl. capacity each, arranged as shown in Fig. 1. These tanks had suffered appreciably in the past from external corrosion on the bottoms. Repairs constituted quite an outlay and therefore prompted an investigation as to the feasibility of applying cathodic protection.

At the outset of the survey, a portable generator was set-up and two successive tests were conducted. The readings of these two tests are indicated on Fig. 1, prefixed by the letters (A) and (B), representing the first and second surveys, respectively. The test unit consisted of a portable welding generator and a ground bed for each test made-up of ten 10-ft. lengths of junk 6-in. pipe buried vertically, 10 ft. apart. While each test was in operation, pipe-to-ground and tank bottom-to-ground potentials were determined and re-

Fig. 1. Data of the four surveys made are recorded on this plat of the tank farm



corded for the structures in the vicinity of the test unit. These readings, made with a high-resistance-type voltmeter and a copper-sulphate electrode, were recorded, uncorrected, on a large scale map as shown in Fig. 1. It should be noted that the first test was operated with an output of 75.5 amp. at 31 v., and the second test with an output of 78 amp. at 24 v. Negative connections to more than one tank were made for each test in order to obtain a maximum spread of current.

On the basis of having a potential-to-ground of at least 0.80 v. negative, it was noted that four tank bottoms were completely protected on each test. The potential on nearby bottoms was also raised negatively to a marked degree. Based on these gratifying results and other factors, it was estimated that the installation of four units having a rating of 15 v. and 100 amp. each would completely protect the entire tank farm. Power was already being purchased for lights and small booster pump units, so the cost of this additional power proved to be very economical. After estimating the cost of power, maintenance, and depreciation on this proposed installation and comparing this figure with the cost of repairs due to external corrosion, it was found that a surprising annual saving could be effected. In other words, the cost of reconditioning each tank bottom at 10-year intervals, which was previously experienced, would be eliminated and the resulting saving would pay for the installation in one year.

The four units were installed as shown in Fig. 1. Fig. 2 shows the method used for housing each set. The foundation is of concrete and the building is of corrugated iron with wooden frame. Doors are provided on both sides so that the motor-generator is easily accessible for repairs and adjustments. Each unit consists of a 15-v., 100-amp., motor-generator driven by 220-v. three-phase electrical power. The engineering data for each unit when installed were as follows:

UNIT NO. 1

Output . . . . 86 amp. at 15 v.
Ground circuit resistance . 0.175 ohm
Ground bed—200 ft. of 8-in. pipe buried horizontally at a depth of 2½ ft.; plus 10 sections of 6-in. pipe, 10 ft. long, buried vertically on 10-ft. centers.

UNIT NO. 2

Output . . . . . 90 amp. at 11 v.
Ground circuit resistance . 0.122 ohm
Ground bed—275 ft. of 8-in. pipe buried horizontally at a depth of 3 ft.; plus 10 sections of 6-in. pipe, 10 ft. long, buried vertically on 10-ft. centers.

UNIT NO. 3

Output . . . . . 76 amp. at 15 v.
Ground circuit resistance . 0.197 ohm
Ground bed—300 ft. of 8-in. pipe buried horizontally at a depth of 3 ft. Salt (2000 lb.) was added due to sandy soil conditions.

UNIT NO. 4

Output . . . . . 72 amp. at 15 v.
Ground circuit resistance . 0.208 ohm
Ground bed—300 ft. of 8-in. pipe buried horizontally at a depth of 3 ft.

No. 00 special underground copper cable was used for positive connections to the ground beds. No. 00 rubber-covered double-braid copper cable was installed underground for the negative connections. This latter was used as an economy measure as, being on the negative side, it would be protected along with the tank bottoms and therefore would not suffer from electrolytic action.

With the units operating under the above conditions, potentials of the structures to soil were taken and noted on the map in Fig. 1, whereon these readings appear as the figures prefixed by the letter (C). With the exception of possibly one tank, all tank bottoms and connecting pipe lines were indicated as being protected, as negative potentials at all points averaged 0.80 v. or more. It was also found that all coated incoming and outgoing trunk lines were protected for 1½ miles from the property line; the bare trunk lines, however, were not materially benefited beyond the confines of the tank farm. Some of these trunk lines had previously been equipped with insulating flanges, so these flanges were bonded over to allow protection to extend as far as possible.

Fig. 2. Motor-generator installation for protecting oil storage tank bottoms and tank farm pipe lines

In taking potential readings on the tanks, contact was made to the angle iron around the bottom. There was some question as to what potential was being maintained at the center of the bottom. Obviously, this was something that could not be conveniently determined; however, some of the tanks were open for repairs at the time so inspection holes were cut in the center of the bottoms of the open tanks and readings taken. The results indicated that negative potentials at the centers were generally 0.05 v. lower than the average values as noted on the outside bottom angle irons.

During January, 1940, after the system had been in operation for nine months, a resurvey of this tank farm was made by repeating the method used in obtaining the previous potential readings. The figures representing these readings are prefixed by the letter (D) in Fig. 1. The output of each unit had changed somewhat since the first survey. The current output of Unit Nos. 1 and 2 had increased slightly and that of Nos. 3 and 4 had decreased. The ground circuit resistance for each installation had changed in the reverse order. The results of this recheck indicated that protection for the whole tank farm was still being maintained with the exception of the one tank bottom previously mentioned. Even though two of the units were operating with reduced outputs, potentials-to-ground were generally higher, due to polarization of the metallic surfaces.

A check of power bills for several months before and after the installations were made indicated that power costs for operating the units averaged a little more than the originally estimated cost. This was due to small rectifiers having been added to three of the generators to excite the shunt fields separately, thus materially decreasing the efficiency of the system. This separate excitation was made necessary after it was found that the particular units involved were not stable in operation.

The results so far on this particular cathodic installation are definitely satisfactory. From them the following conclusions may be drawn:

1. Tank farms can be economically protected by the cathodic method.
2. Appreciable savings in power costs can be effected by proper selection of number and location of units.
3. The type of unit used depends (a) on the absence, or presence, of personnel for insuring full-time operation, and (b) on available power.
4. Metal-to-ground potentials on outside angle iron of tank bottoms should average approximately 0.05 v. negatively higher than the accepted potential value for complete protection in order to insure full protection at the center of the bottoms.

P 621.
P 213.3

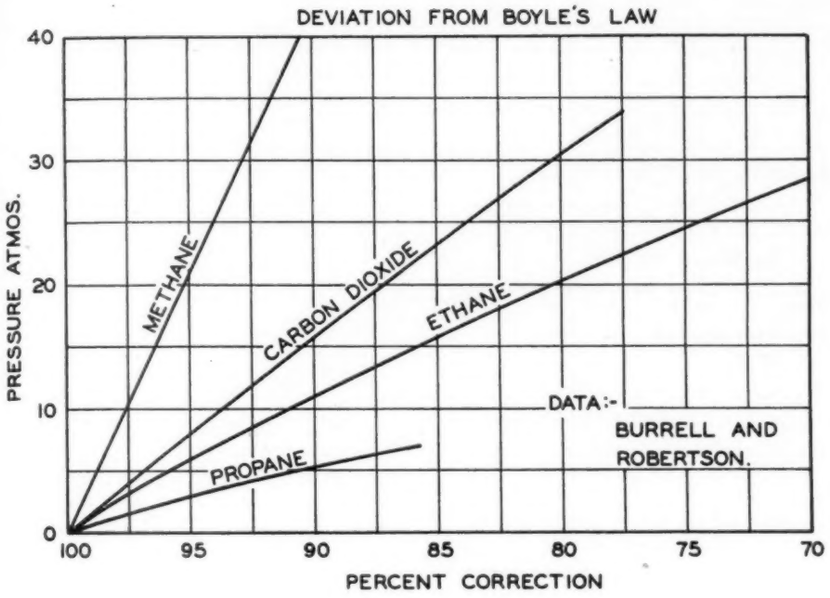


Fig. 1.

A PETROLEUM ENGINEER EXCLUSIVE FEATURE

By

PAUL F. MARX

Supercompressibility Data Correlated Into Usable Form

By averaging the test data at two pressures and making appropriate gravity corrections to compensate for nitrogen, a slide rule is prepared that aids in approximating compressibility factors and percent deviations from Boyle's Law

IN THE hydrocarbon paraffin series denoted by C_nH_{2n+2} we observe a relationship of carbon to hydrogen. Taking a ratio of the molecular weight of carbon (12) to the molecular weight of hydrogen (1) we obtain:

$$C/H = \frac{12n}{1\ (2n+2)}$$

for methane, $n = 1$ or CH_4

$$C/H = \frac{12}{4} = 3$$

for ethane, $n = 2$ or C_2H_6

$$C/H = \frac{24}{6} = 4, \text{ etc.}$$

This relationship C/H, will be used to link supercompressibility and specific gravity into a usable form.

According to the data by Burrell and Robertson of the U. S. Bureau of Mines shown in Fig. 1, the deviations per atmosphere at 15°C. are:

Methane = CH_4 = 0.228 percent

Ethane = C_2H_6 = 0.900 percent

If one atmosphere is considered as 14.65 lb. per sq. in., the percent deviations per lb. become:

$CH_4 = 0.0156$

$C_2H_6 = 0.0614$

Incidentally, nitrogen is very small:

$N_2 = 0.0007$

As methane and ethane are the principal constituents in natural gas, these are the influencing factors and will be used to develop relationships.

Letting x and y, respectively, denote the percentage of methane and ethane in a gas mixture, then:

$$x + y = 100 \quad . \quad . \quad . \quad . \quad (1)$$

and from the foregoing C/H ratios:

$$\frac{12x + 24y}{4x + 6y} = C/H \quad . \quad . \quad . \quad . \quad (2)$$

By assuming values of C/H between methane and ethane, the various values of x and y can be determined by solving equations (1) and (2) simultaneously. The sum of x times 0.0156 plus y times 0.0614 is plotted against C/H to produce the curve shown in Fig. 2.

The specific gravity of the mixtures is also plotted against the C/H ratio, as in Fig. 3.

As the specific gravity and the percent deviation per pound bear a direct relationship to the C/H ratio, they also assume a relationship to one another.

The data of S. E. Silcox, Standard Oil Company of California, plotted in Fig. 4, as well as other information on average gases, show that for a temperature change of 20 degrees there is a

PAUL F. MARX

received his education at the Western Military Academy, Alton, Illinois, and the Colorado School of Mines—Since 1921 he has followed experimental and engineering lines and has been affiliated with the following companies: American Metals Company, Ltd., experimental flotation; Standard Oil Company of Indiana, combustion engineer; White Eagle Oil and Refining Company, development department; Skelly Oil Company, propane and butane experimental work; engineer for eight years with the Natural Gas Pipeline Company of America—Since his association a year ago with the Northern Natural Gas Company as engineer he has dealt principally with problems in cathodic protection, electrolysis mitigation, and corrosion.

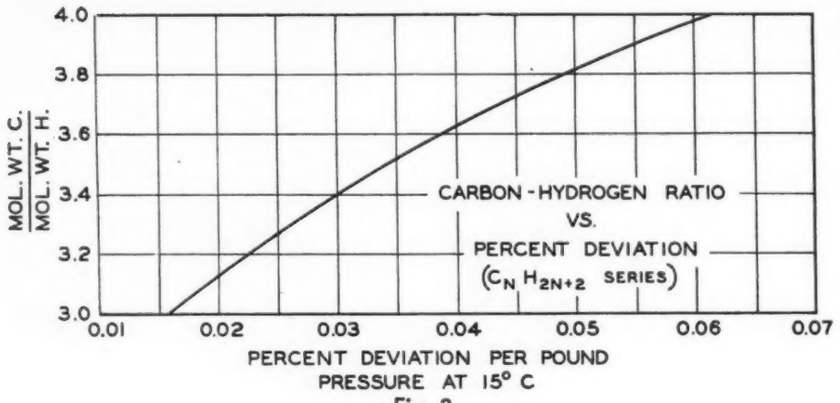


Fig. 2

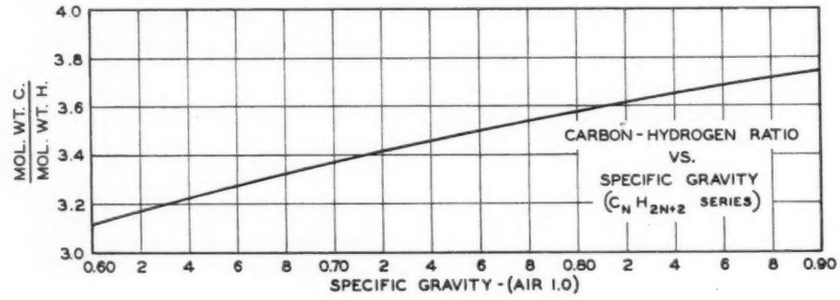


Fig. 3

change of approximately 6 percent in the deviation.

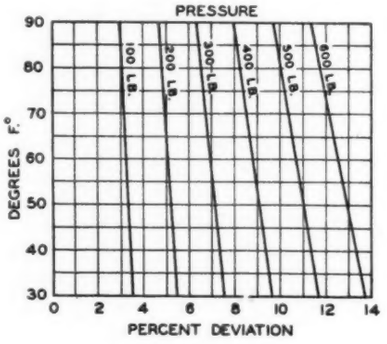
A study of 50-odd samples of natural gas from all parts of the United States showed an average nitrogen content of 5 percent. Five percent of the specific gravity of nitrogen amounts to 0.049.

Using the facts outlined, and shifting the gravity scale to compensate for nitrogen, the compressibility slide rule, included as a part of this article, was constructed. By its use, the orifice meter correction factor or the percent deviation from Boyle's Law may be obtained from the specific gravity of the gas in question.

The rule certainly will aid in engineering calculations and its accuracy has been found to be within 1 percent when compared to actual experimental data available.

Many types of apparatus have been constructed to determine the deviation from Boyle's Law. Careful manipulation and detailed corrections on machines of this type have resulted in a maximum error of 0.085 percent in orifice meter correction factors at 300 lb. per sq. in. absolute pressure on the same gas sample, but the average error is 0.035 percent, which is extremely low.

A method of eliminating many actual tests and numerous calculations, which is accurate within 0.1 percent



(Data by S. E. Silcox)

Fig. 4

of the actual tests, is described as follows:

By means of a compressibility apparatus, data at two temperatures should be obtained. Assume the following are the test data:

Temp., °F.	*Pressure, lb. per sq. in. abs.*	*Percent deviation at 14.65 lb. per sq. in.*
60	325.39	5.04
60	239.85	3.60
60	164.34	2.30
60	114.49	1.51
60	64.59	0.71
39.90	320.02	5.54
39.90	239.82	3.97
39.90	164.76	2.55
39.90	114.61	1.64
39.85	64.54	0.75

Actually, these compressibility curves are concaved downward near the zero point. A curve of this type is of the form $y = a + bx + cx^2$. As this form is difficult to manipulate and as the working portion of the curve is located as it is, the curve will be put into the form:

$$y = mx + b$$
$$\text{or } P = md + b$$

The curve of the average test temperature of 60°F. will be solved by the Method of Least Squares:

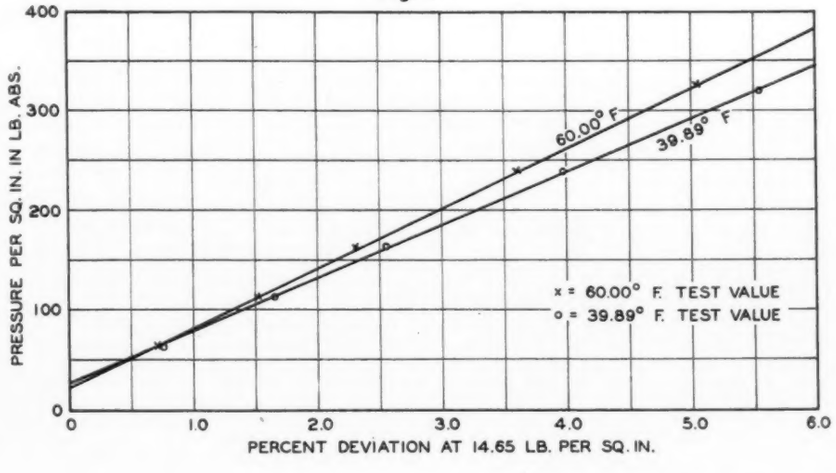
Let P = the absolute pressure
d = percent deviation
m = slope of curve
b = crossing point on "y" axis

Substituting values:

$$325.39 = 5.04\,m + b$$
$$239.85 = 3.60\,m + b$$
$$164.34 = 2.30\,m + b$$
$$114.49 = 1.51\,m + b$$
$$64.59 = 0.71\,m + b$$

Multiplying each equation by its coefficient of m and adding the resulting equations equals:

Fig. 5



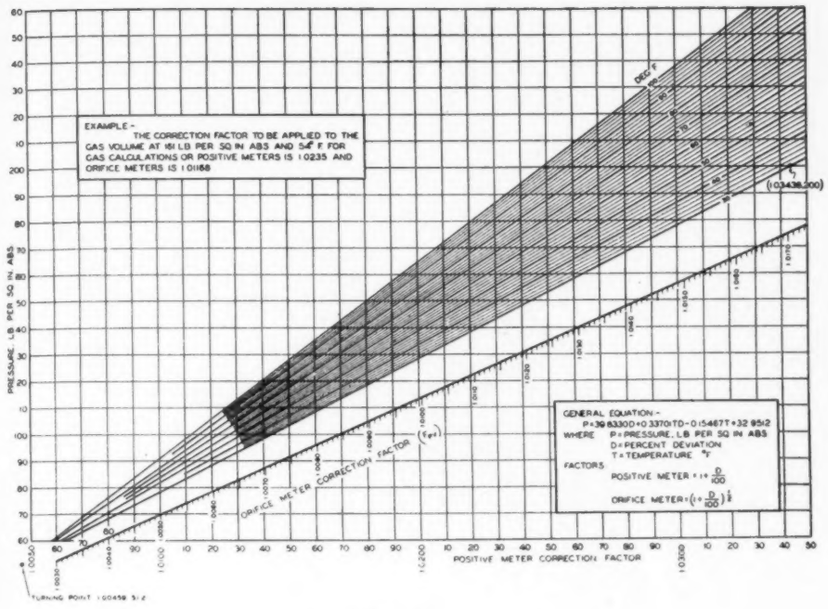

EXAMPLE -
THE CORRECTION FACTOR TO BE APPLIED TO THE GAS VOLUME AT 151 LB. PER SQ. IN. ABS. AND 54° F. FOR GAS CALCULATIONS OR POSITIVE METERS IS 1.0235 AND ORIFICE METERS IS 1.0168
GENERAL EQUATION -
WHERE P = PRESSURE, LB. PER SQ. IN. ABS.
D = PERCENT DEVIATION
T = TEMPERATURE °F
FACTORS
POSITIVE METER
ORIFICE METER
PRESSURE, LB. PER SQ. IN. ABS.
ORIFICE METER CORRECTION FACTOR
POSITIVE METER CORRECTION FACTOR
TURNING POINT 1.00459 51.2

Fig. 6

$3100.1464 = 46.4358m + 13.1600\,b$ . . . . . (3)

Multiplying each equation by its coefficient of b and adding, results in:

$908.66 = 13.16m + 5b$ . . . (4)

Solving equations (3) and (4) simultaneously gives:

$b = 23.6709$

$m = 60.0536$

Expressing in the form:

$y = m\,x + b$

$P = 60.0536\,d + 23.6709$ . . . . . (5)

This equation is a mathematical average of the experimental 60°F. points.

In a similar manner the curve for the average temperature line of 39.89°F. results in the equation:

$P = 53.2763\,d + 26.7814$. (6)

Combining equations (5) and (6) into one equation designed to satisfy any temperature:

$$P = \left[53.2763 - \left(\frac{60.0536 - 53.2763}{60.00 - 39.89} \times 39.89\right)\right]d + \left(\frac{60.0536 - 53.2763}{60.00 - 39.89}\right)td + \left(\frac{23.6709 - 26.7814}{60.00 - 39.89}\right)t + \left[26.7814 - \left(\frac{23.6709 - 26.7814}{60.00 - 39.89} \times 39.89\right)\right]$$

Simplifying:

$$P = 39.8330\,d + 0.33701\,td - 0.15467t + 32.9512 \quad . . . . . (7)$$

where P = pressure, lb. per sq. in. abs.
d = percent deviation
t = temperature, °F.

As d is the percent deviation from Boyle's Law at 14.65 lb. per sq. in., the true volume of the gas in question when expanded from high pressure should be multiplied by a factor of:

$$1 + \frac{d}{100} \quad . . . . . (8)$$

This also applies to positive meter calculations. In computations, if the gas is being compressed the volume diminishes by the percent deviation.

Fig. 5 was constructed by solving equations (5) and (6) simultaneously:

$P = 60.0536\,d + 23.6709$. (5)

$P = 53.2763\,d + 26.7814$. (6)

$0 = 6.7773\,d - 3.1105$

$d = 0.458959$

$P = 51.2330$

Using equation (8) the common turning point for the family of curves in Fig. 6 has the coördinates:

(1.00459, 51.2)

By substituting values for t in equation (7), and a value for P within the pressure range encountered, the resulting values together with the foregoing turning point values are used as coördinates of the straight lines.

For example:

Assume $t = 30°F.$

$P = 200$ lb. per sq. in. abs.

Substituting in equation (7) gives:

$200 = 49.9433\,d + 28.3111$

whence $d = 3.438.$

The coördinates of the two points on the 30°F. deviation factor curve then are:

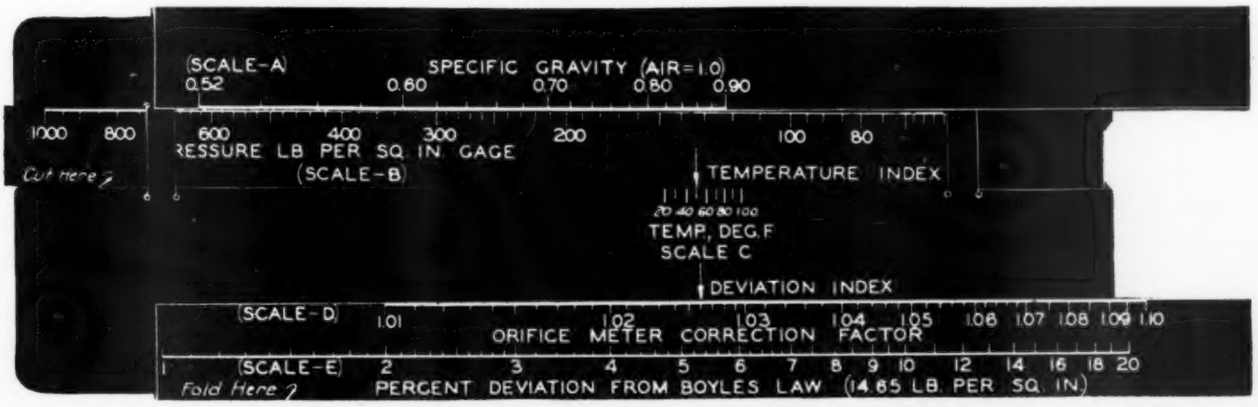
abscissa	ordinate
1.00459	51.2
1.03438	200.

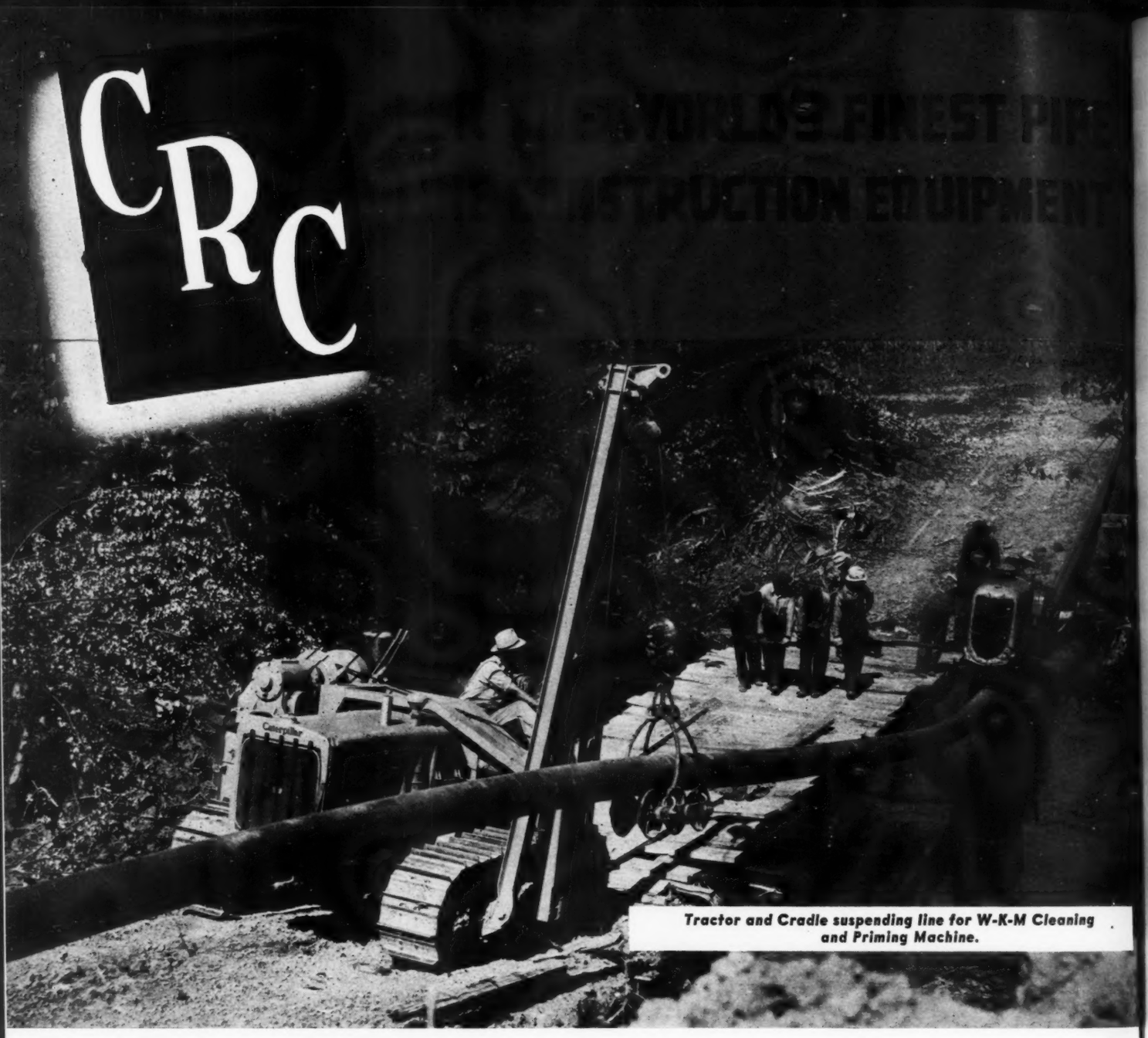
Fig. 6 shows the family of curves derived in a manner similar to the 30°F. temperature line just calculated.

In orifice meter calculations, the gas volumes determined from the meter charts should be multiplied by a factor (F_{pv}), which is:

$$F_{pv} = \left(1 + \frac{d}{100}\right)^{\frac{1}{2}} \quad . . (9)$$

Assembled rule with slides set to illustrate example given on back of rule





Tractor and Cradle suspending line for W-K-M Cleaning and Priming Machine.

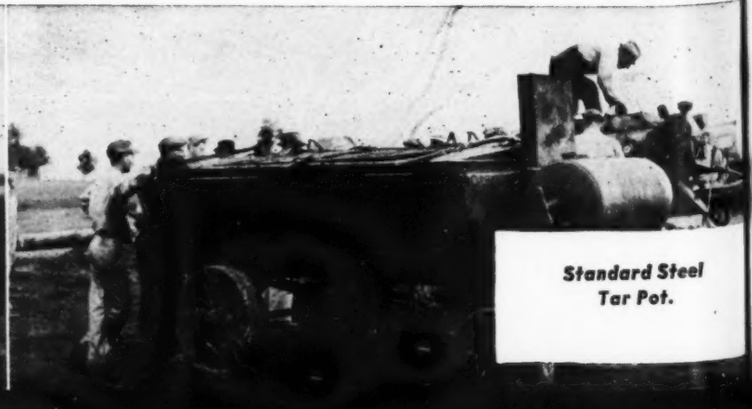
There is no substitute for experience . . . especially in the selection of pipe line equipment. Through our manufacturing associates and our active field service on nearly all pipe line construction and reconditioning, we offer the *most modern* pipe line construction material and equipment.

Crutcher-Rolfs-Cummings

PIPE LINE EQUIPMENT AND MATERIALS

HOUSTON, TEXAS, U. S. A.

Johns-Manville Coating and Wrapping Machine.



Standard Steel Tar Pot.

This factor is included in Fig. 6. It is the square root of 1 plus the percent deviation expressed as a decimal and laid off on the line shown, which has any convenient angle.

If a family of curves is constructed for only the orifice meter correction factor, F_{pv}, the square root of the abscissa values at the turning point and $P = 200.$ are used. A straight line drawn between the following coordinates:

abscissa	ordinate
1.00229	51.2
1.01704	200.

will be the 30°F. curve for F_{pv}. Using this method will introduce an error of only 0.01 percent, as the square root of a straight line is not a straight line.

When tables of F_{pv} values are set up where numerous calculations are necessary, the equations are transformed as follows:

$$F_{pv} = 0.0000991483 \quad P + 0.997214 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (12)$$

The above formula is obtained by substituting the coördinates given for the 30°F. curve, in the following formula, the equations then being solved simultaneously.

Since

$$y = mx + b$$

then

$$P = mF_{pv} + b$$

$$51.2331 = m\ 1.00229 + b \quad . \quad (10)$$

$$200.000 = m\ 1.01704 + b \quad . \quad (11)$$

whence $m = 10085.9$

$b = -10057.8$

or

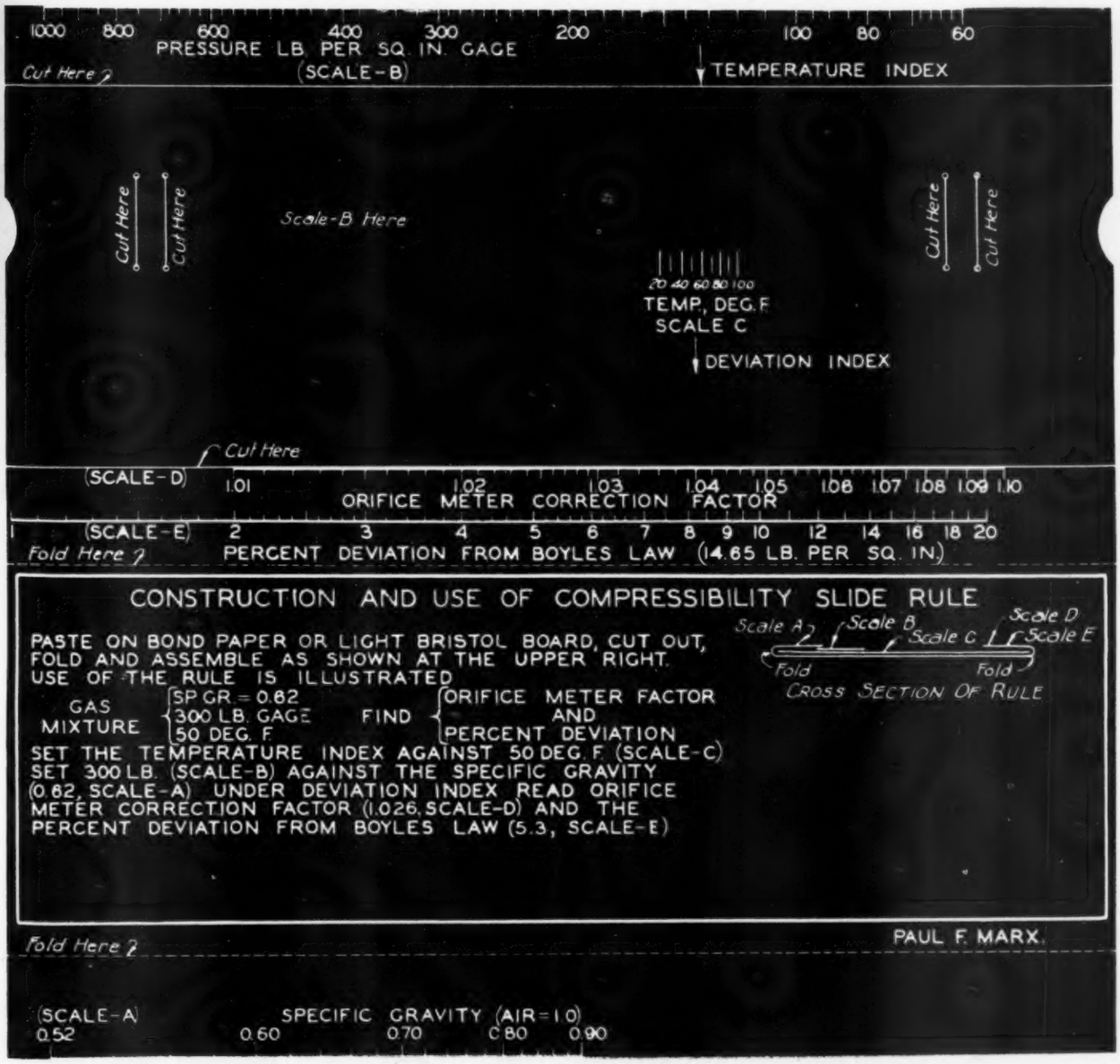
$$P = 10085.9\ F_{pv} - 10057.8 \quad . \quad (13)$$

transposing, equation (12) is obtained.

An equation of this type may easily be used in a calculating machine as it only has a constant and a multiplying factor.

Orifice meter factors derived in the foregoing manner outlined have been found to vary from actual tests an average 0.02 percent over a four-year period; the individual maximum variation was 0.07 percent.

Compressibility slide rule that may be cut out and assembled as directed


1000 800 600 400 300 200 100 80 60
PRESSURE LB PER SQ. IN. GAGE
Cut Here
(SCALE-B)
TEMPERATURE INDEX
Cut Here
Cut Here
Scale-B Here
Cut Here
Cut Here
20 40 60 80 100
TEMP, DEG.F
SCALE C
DEVIATION INDEX
Cut Here
(SCALE-D) 1.01 1.02 1.03 1.04 1.05 1.06 1.07 1.08 1.09 1.10
ORIFICE METER CORRECTION FACTOR
1 (SCALE-E) 2 3 4 5 6 7 8 9 10 12 14 16 18 20
Fold Here
PERCENT DEVIATION FROM BOYLES LAW (14.65 LB. PER SQ. IN.)
CONSTRUCTION AND USE OF COMPRESSIBILITY SLIDE RULE
PASTE ON BOND PAPER OR LIGHT BRISTOL BOARD, CUT OUT, FOLD AND ASSEMBLE AS SHOWN AT THE UPPER RIGHT. USE OF THE RULE IS ILLUSTRATED
GAS MIXTURE { SP GR = 0.82, 300 LB. GAGE, 50 DEG. F } FIND { ORIFICE METER FACTOR AND PERCENT DEVIATION }
SET THE TEMPERATURE INDEX AGAINST 50 DEG. F. (SCALE-C)
SET 300 LB. (SCALE-B) AGAINST THE SPECIFIC GRAVITY (0.82, SCALE-A) UNDER DEVIATION INDEX READ ORIFICE METER CORRECTION FACTOR (1.026, SCALE-D) AND THE PERCENT DEVIATION FROM BOYLES LAW (5.3, SCALE-E)
Scale A
Scale B
Scale C
Scale D
Scale E
Fold
Fold
CROSS SECTION OF RULE
Fold Here
PAUL F. MARX.
(SCALE-A)
SPECIFIC GRAVITY (AIR=1.0)
0.52 0.60 0.70 0.80 0.90

WHY PIPE LINEM

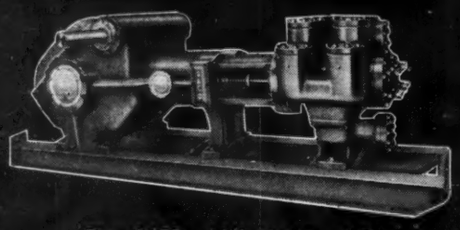


Fig. 2652. 12" stroke—176 bbls. at 1500 lbs. to 592 bbls. at 500 lbs.

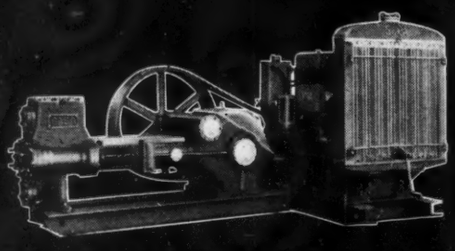


Fig. 1741, with Diesel Drive—250 bbls. at 600 lbs. to 502 bbls. at 300 lbs.

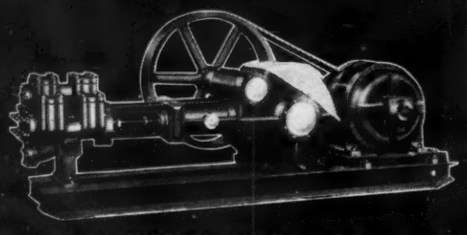


Fig. 1742. Electric Motor Drive. 54 bbls. at 1400 lbs. to 250 bbls. at 600 lbs.

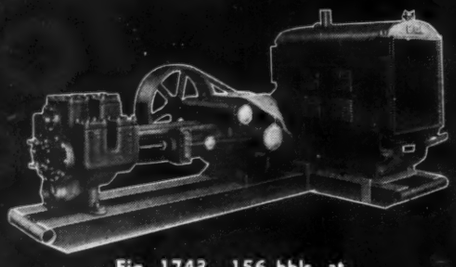
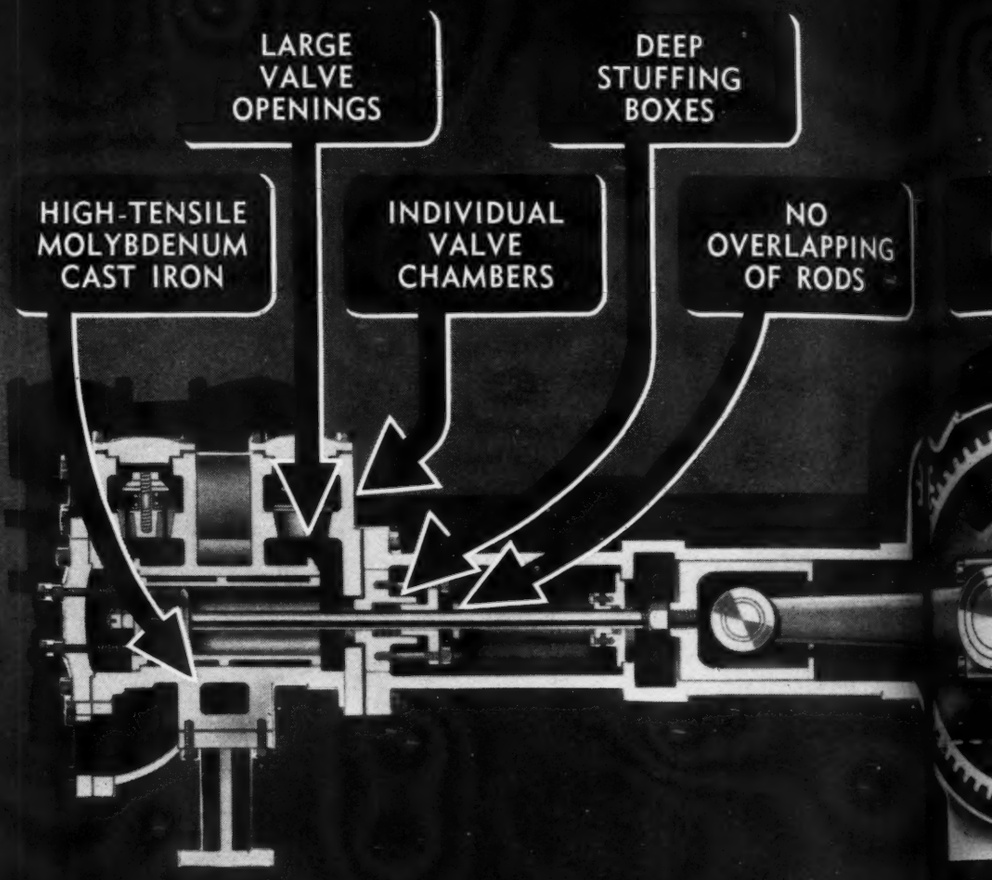


Fig. 1743. 156 bbls. at 925 lbs. to 578 bbls. at 260 lbs.

Fig. 201. GASO Rodline Pump. 30.96 bbls. at 18 strokes, to 41.28 bbls. at 24 strokes.



THE dominating position of GASO Pumps in the field of oil pipe line pumps is not due to luck or to aggressive salesmanship. It is due to **merit of product**, achieved through a quarter century of strict specialization. GASO Pumps are built exclusively for oil pipe line use, and are designed by engineers of long experience to deliver exceptional performance in this service. Some of the features which have made them the choice of pipe line engineers, are here listed:

High-Tensile-Strength Molybdenum Cast Iron is used for fluid-end casting.

Extra-Large Valve Openings and Fluid Passages permit proper filling at highest speeds.

Individual Valve Chambers.

Extra-Deep Stuffing Boxes give tightness without undue tension.

Long Frames Prevent Overlapping of Piston Rods. Pumped fluids will not reach crankcase.

Herringbone Gears are Center-Mounted on Shafts to equalize loads on bearings.

GASO

EMEN PICK GASO

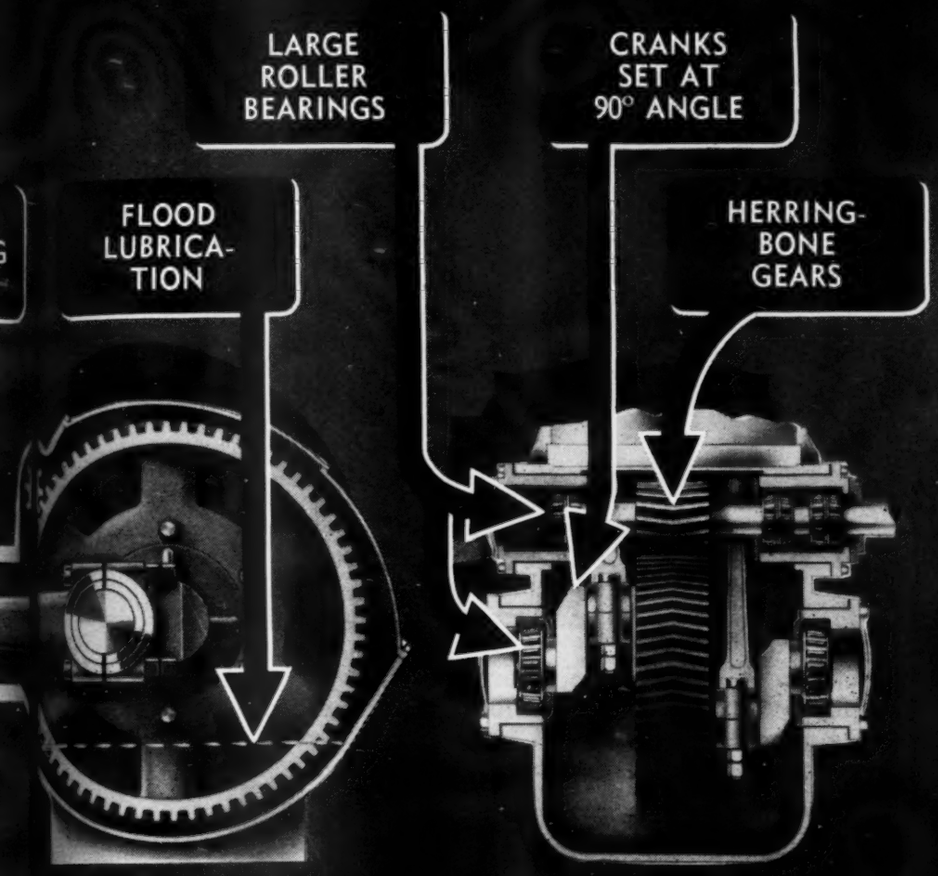


Fig. 2050-S. Portable Unit. 59 bbls. at 1000 lbs. to 255 bbls. at 250 lbs.

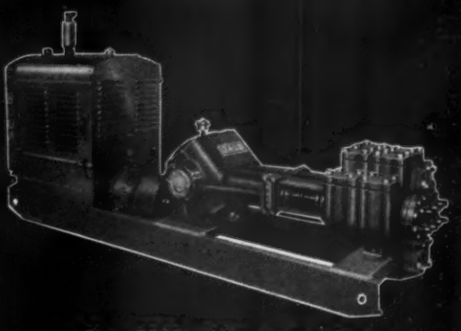


Fig. 2249. Also mounted on trailer. 46 bbls. at 750 lbs. to 126 bbls. at 300 lbs.

Fig. 1550. 59 bbls. at 1000 lbs. to 255 bbls. at 300 lbs.

Extra-Large Roller Bearings mount crank, pinion and worm shafts, each operating in separate removable housing sealed off from crankcase oil.

Cranks Set at 90-Degree Angle give overlapping piston stroke assuring smooth flow.

Flood-Lubricated gears, crosshead and connecting-rod bearings, by oil bath in enclosed crankcase.

Uniform Wear on Ring Gears, assured by worms of hardened alloy steel, ring gears of bronze.

Versatility. Interchangeable liners; pistons, rings and piston rods of any materials specified; valves of any type desired.

Replacement Parts that Fit.

Send for catalog, or refer to Gaso Section, Composite Catalog.

Gaso Pump & Burner Mfg. Company, Tulsa, Okla. Export Office: 149 Broadway, New York. Houston: 2108 Tangley. Los Angeles: Service Oil Field Supply Co., 5333 S. Riverside Drive.

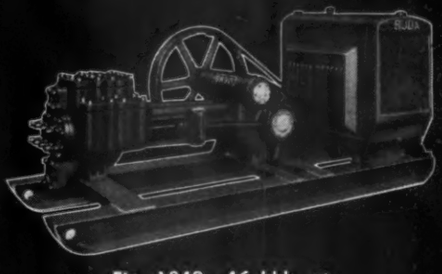


Fig. 1849. 46 bbls. at 900 lbs. to 126 bbls. at 350 lbs.

Fig. 301. Piston Power Pump. 24 to 30-inch stroke. 31.73 to 157.36 bbls. per hour.

PUMPS

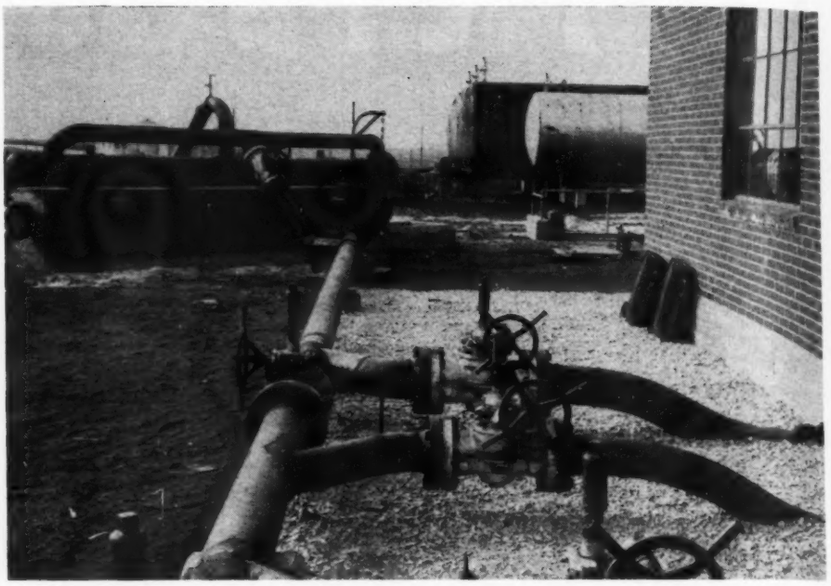


Fig. 1. Gravity separator in background is used for removing sediment from gasoline prior to entering pumps

A PETROLEUM ENGINEER EXCLUSIVE FEATURE

By
STANLEY LEARNED
Chief Engineer, Phillips Petroleum Company

Operating Experience Dictates Advanced Design of New Gasoline Pipe Line

Station manifolds providing extreme flexibility in operation, gravity separators requiring only periodic cleaning, and new streamlined approaches to suspension bridge are features of line built by the Illana Company as a plant facility for Phillips Petroleum Company

BUILT as a plant facility of Phillips Petroleum Company, the gasoline pipe line recently completed by the Illana Company from East St. Louis, Illinois, to East Chicago, Indiana, incorporates certain features that are of engineering interest because of the departure from usual design.

Aboveground Sediment Traps

At each station, the sediment traps have been placed aboveground as a convenience to the operator and to eliminate corrosion, hazard to workmen, and fire danger.

An accompanying picture (Fig. 1), taken before construction of the station was entirely completed, shows the arrangement of one of the traps. An 8-in. line enters at the top of the trap, the fluid and sediment dropping into a 16-in. horizontal pipe where the stream is split to flow in two directions. Creation of this dual stream has the effect of reducing the velocity of flow thus permitting the sediment and water to drop through four connections into a 10-in. collecting pipe as the fluid being pumped leaves the 16-in. pipe through the upper connections shown, and enters the suction line of the pumps. Sediment is removed periodically from the ends of the collecting pipe through flanges. From the underside of the collecting pipe five 2-in. drains permit water and what small volume of gasoline may still be intermixed with it, to be piped to a gravity separator in which the water is removed. The gasoline recovered from the separator is collected in a sump pit prior to its entering the pump suction.

STANLEY LEARNED

was graduated from the University of Kansas with a B.S. degree in civil engineering (1924)—In 1935, received degree of civil engineer from same school — Association with Phillips Petroleum Company began in 1924.

Operating procedure calls for the running of scrapers through the line at two-week intervals. This practice should avoid an excessive accumulation of rust or other sediment in the line and maintain maximum flow efficiency.

Flexibility in Manifold Operation

Aboveground headers and manifolds also are being used by the company at stations for the first time, and, although not an innovation, the somewhat intricate manifolds at terminals also are placed aboveground. An isometric drawing (Fig. 2) of the manifold at the East Chicago terminal is reproduced as an example of what is considered "good practice" by operators of gasoline pipe-line systems. Although this particular manifold is larger than some of the others on the company's system, the same general plan is employed at all terminals.

A drawing similar to the one shown is provided operators at each terminal for their daily use, except that such drawings also include a tabulation of the valve numbers, giving the size and function of each valve and the manner in which it is operated.

East Chicago Terminal

To blend, load, and store gasolines the East Chicago terminal has 11 pumps and a total of 676,000 bbl. of storage. Three of the pumps, each driven by a

40-hp. motor, are rated at 1000 gal. per min. at 1750 r.p.m. against a head of 150 ft. Four pumps are rated 750 gal. per min. at 1750 r.p.m. against a head of 120 ft., and the remaining four are rated at 300 gal. per min. at 1750 r.p.m. against a head of 100 ft. The 750-gal. pumps are driven by 25-hp. motors and the 300-gal. pumps by 10-hp. motors. The tankage consists of six 80,000-bbl. tanks, four 20,000-bbl. tanks, and four 10,000-bbl. tanks —all of the floating-roof type; two 20,000-bbl. spheroids and thirty-six 1000-bbl. "blimps."

Suspension Bridge

Approximately two miles east of East St. Louis, Illinois, in the navigation district, it was necessary to make a canal crossing. Engineering studies indicated a suspension bridge as the most economical method to adopt, and its manner of construction includes several features that are deemed worthy of mention. The main supporting towers are set in concrete and rise 73 ft. above the surface of the ground. The pipe is carried through the towers at a height of 60 ft. From tower to tower the distance is 300 ft. and from tower to anchor the distance is 250 ft. The most unusual feature of the bridge is the fact that the pipe is carried in part on the main supporting cables rather than being suspended therefrom. Fig. 3 is illustrative of the method employed and, as can be seen, from the anchors to the towers the 8-in. line rides the cables. Between towers the pipe is suspended by cables, in keeping with customary practice. The purpose of carrying the pipe on the cable in this manner was to eliminate possible tampering by placing it too high for ready accessibility and, as some of the cables were eliminated, a reduction in cost was effected.

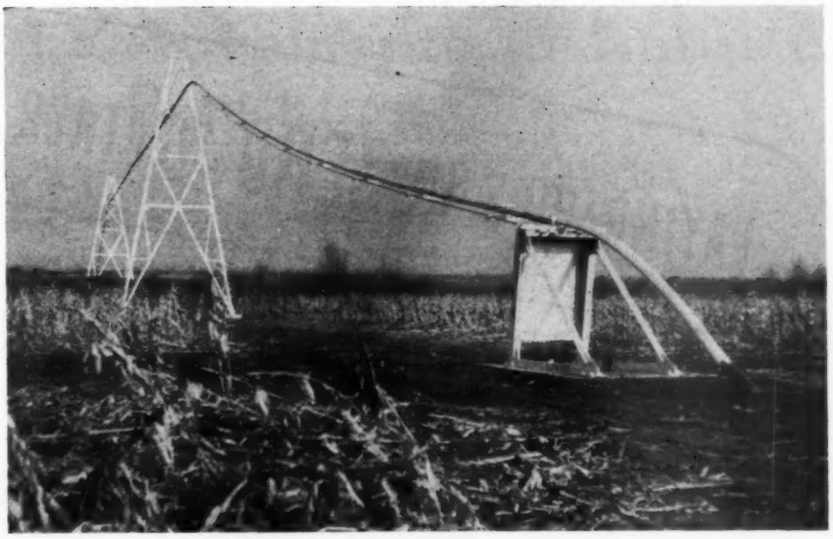


Fig. 3. Supported at intervals on members joining two cables, the line is flexed slightly in this streamlined approach to the suspension bridge spanning a canal

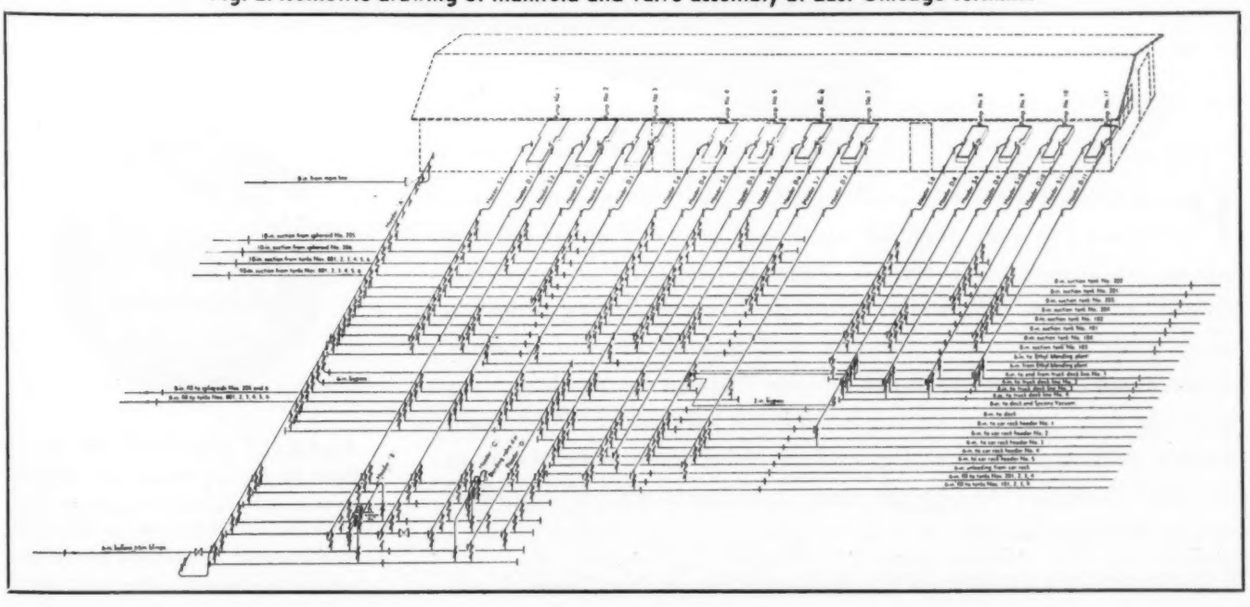
Line Testing

The pipe line when completed was given a 1500-lb. water test, and because of the desirability of avoiding all possibility of internal corrosion, which is of more than usual importance when a gasoline line is involved, the water was treated with caustic soda to raise its pH value to a minimum of 10 before pumping it into the line.

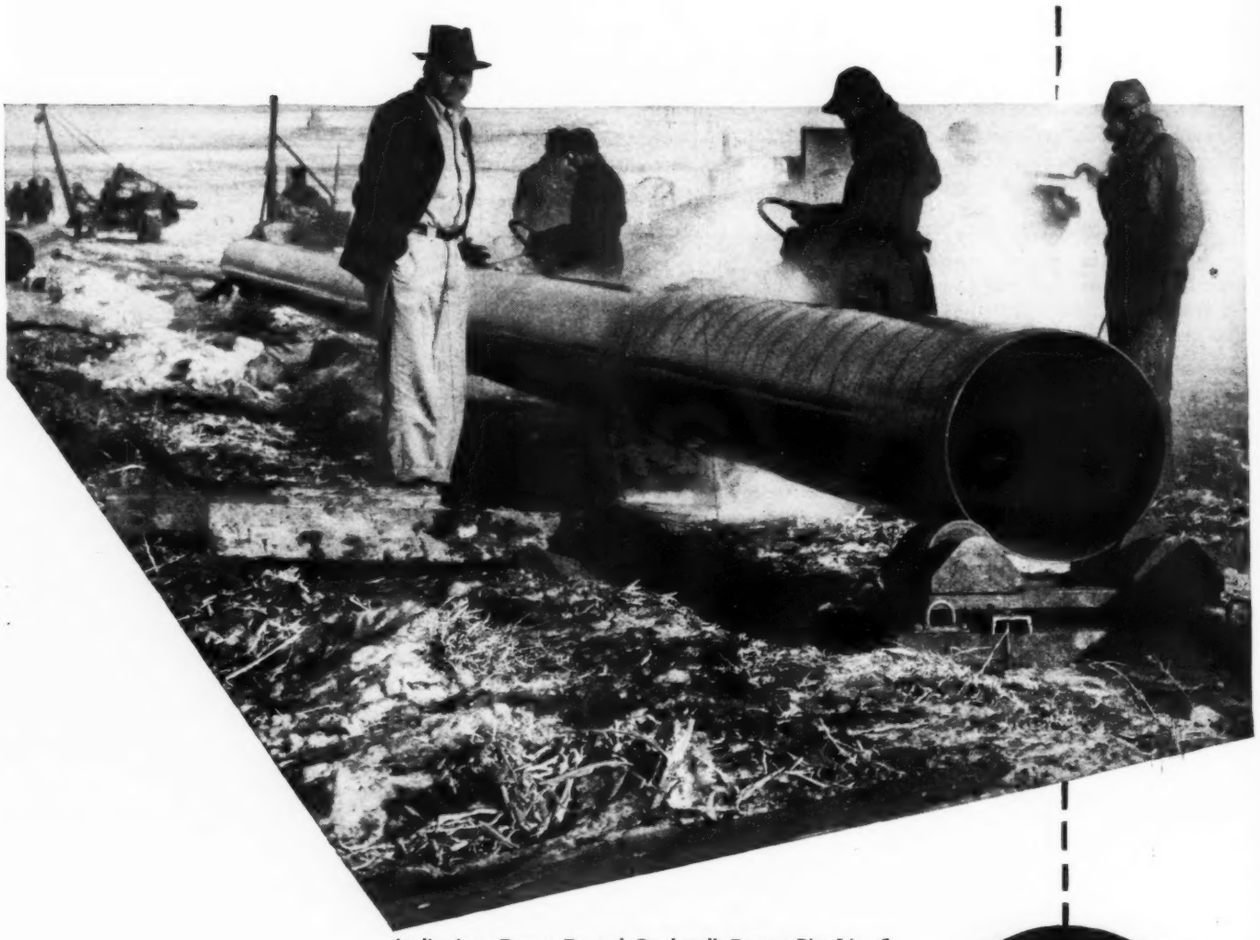
General Information

In 1930 the Phillips Pipe Line Company, a subsidiary of the Phillips Petroleum Company, completed a 681 mile gasoline pipe line from Borger, Texas, to East St. Louis, Illinois. That line is now in operation as a common carrier. The new line extending from East St. Louis to Chicago, Illinois, a distance of 271 miles, is operated by the Phillips Petroleum Company as a plant facility. The line is of 8-in. diameter and was electric welded. Stations were built at Dupo, Hillsboro, Maroa, and Piper City, all in Illinois, and terminals at Decatur and Kankakee, Illinois, and East Chicago, Indiana. Each station is equipped with two 4-stage centrifugal pumps driven through speed increasers by 300-hp. engines that use butane as fuel.

Fig. 2. Isometric drawing of manifold and valve assembly at East Chicago terminal



LAYING PIPE IN ZERO WEATHER



Application—Barrett Enamel. Panhandle Eastern Pipe Line Co.

PANHANDLE EASTERN PIPE LINE COMPANY'S construction program this year demands out-of-season work under adverse winter conditions. But Barrett Enamels, designed to overcome unusual obstacles, performed faultlessly. Not a foot of pipe . . . no coatings on Dresser couplings, lost because of cold weather. Again Coal-Tar Pitch, of which Barrett Enamels are made, proves itself the most stable of known bituminous substances. And again Barrett skill in manufacturing and careful Barrett supervision in the field illustrate two of the many reasons farsighted engineers specify Barrett Enamels.

THE BARRETT COMPANY 40 Rector Street, New York, N. Y.

Barrett PIPELINE ENAMEL

BARRETT SERVICE With Barrett Field Service assistance and rigid inspection, The Barrett Company provides a unique follow-through to assure the best possible results from Barrett protective coatings. Inquiries are invited.

P 623.
P 625.

Changes and Improvements in Natural Gas Pipe Lines

Developments in scrapers or "go-devils," use of thin wall pipe and the manner of its protection, installation of streamlined connections in line construction, and improvements in coating machines among recent contributions to pipe-line progress

By J. STANLEY STEVENSON
Chief Engineer, Panhandle Eastern Pipe Line Company

LONG recognized as an ideal form of energy, readily adaptable to many and varied uses and applications, gas is becoming increasingly important in the economic order. Volumes could be written about the rapid growth and progress during the last decade alone, of the natural gas industry in this country. In this article will be described briefly only a few of the more important recent developments and trends in the construction and operation of gas transmission lines.

The first half of the last decade witnessed the completion of the world's first long-distance, large-diameter, high-pressure natural gas pipe lines. As consumer demand increased, the operating companies began to concern themselves with attaining maximum deliveries. With the discovery of the formation of gas hydrates in pipe lines, in the presence of water, gas dehydration plants were designed and placed in operation on the longer lines. As these plants were effective in lowering the dew point of the gas to where condensation would not take place in the lines at minimum line temperatures and maximum gas pressures, the original transmission efficiencies and capacities of the lines were, in large measure, restored.

Markets served by these newly built lines in the Mid-Continent continued to develop, and finally operating companies again were faced with the necessity of providing increased delivery capacities. Engineering studies of capacities and actual flow tests of the transmission lines brought the realization that the interior walls of some of these lines were roughened and coated to the extent that their gas-carrying capacities were greatly reduced. This meant that in the worst instances loops must be constructed or additional compressor facilities installed to handle the increasing loads.

Gas Pipe Line Cleaners Developed

It is the opinion of the writer that the recent development of several types of cleaners, or "go-devils," and their successful use in natural gas pipe lines, is one of the outstanding contributions during the last four years to the operation of these lines.

J. STANLEY STEVENSON

obtained his engineering education at Ohio State University—Upon his return from overseas after the World War, where he served as a captain in the Rainbow Division, he was employed by the Ohio Fuel Gas Company—Left the gas industry and for nine years was a construction engineer in general contracting and railroad construction—In 1929 he again became affiliated with the natural gas industry and soon thereafter was employed by Panhandle Eastern Pipe Line Company—Since 1935 he has served that organization as chief engineer.

Obviously a commercial pipe line can only approach but never attain 100 percent efficiency of a perfectly smooth interior wall pipe, laid straight, level, and having an absolutely uniform inside diameter. Flow efficiencies of operating lines are determined by observing the flow under certain conditions and comparing it to that which would have occurred in the standard line. As a "perfect" pipe line of large diameter and sufficient length obviously is not available for actual tests its flow must be calculated. The flow formula used should recognize the fact that the friction factor is not only a function of the inside pipe diameter and the qualities of the gas but of its velocity as well. Otherwise, tests would not be comparable unless conducted under identical conditions.

The several types of cleaners developed, although differing in certain respects, are essentially alike in the matter of design of cleaning elements, blades, brushes, etc. All are designed to be propelled through the pipe line by gas pressure, with the loosened debris from the pipe wall being carried ahead of the cleaner by the gas stream, and blown from the end of the section of pipe line being cleaned. A pressure differential of about 1 lb. per sq. in., or less, is usually sufficient to move the "go-devil" through the line at a desired speed of about 12 m.p.h. An upstream pressure of about 3 to 5 lb. per sq. in. applied to the cleaner is sufficient to maintain this speed. It is sometimes necessary to pass the cleaner through the lines two or more times to attain best results, but it is believed that once encrusted or corroded lines are thoroughly cleaned they will not have to be cleaned again, provided the gas is sweet, is being dehydrated satisfactorily, and gas scrubbers are used on the lines.

It is difficult even to approximate the average improvement in the flow efficiency of lines that might be attained by use of these cleaners, or scrapers. The actual condition of the interior wall of each line tested and the thoroughness of the cleaning job are factors having wide variation and scope. It is not uncommon, however, for efficiencies to be raised 80 to 92 percent, and flow efficiencies as high as 95 percent have been reported to result from the cleaning of a line.

It is not surprising, therefore, that the condition of the surface of the interior wall of new pipe is receiving increasing attention from gas engineers who are even advising the testing of

newly constructed lines to determine their flow efficiencies.

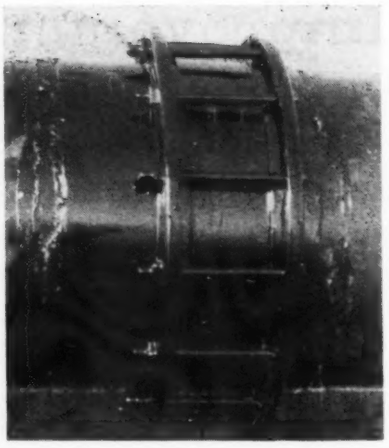
Thin Wall Pipe and Its Protection

It is commonly known that more lighter-weight steel pipe is being used today in the natural gas industry than some 13 years ago. This change to thinner wall pipe was made possible by the use of higher-tensile-strength steel plate and by the development of a new way to manufacture the lighter pipe that has resulted in a product of uniform diameter. Its economy is unquestionably established by the apparently paradoxical fact that a given quantity of gas can be handled by a lower pressure, larger diameter line, at a lower cost. In general the diameter of the pipe is limited only by a practical wall thickness, which in turn establishes its maximum operating pressure.

The increasing use of streamlined, or some form of "Y", connections between looped lines is another example of the efforts of engineers to effect high flow efficiencies. These connections are made in full size and offer a minimum restriction to flow.

As steel is no longer purchased as a protection against the corrosion of pipe lines (extra-heavy wall thickness was long considered the best insurance against pipe failure by corrosion) it is apparent that the industry is alert to the effectiveness of modern corrosion control methods. Much remains to be learned about the corrosion of underground steel pipe, but, on the other hand, much progress has been made in the last few years.

Cathodic protection installations are steadily being made along pipe lines in areas where pipe coatings appear to be giving insufficient protection. This new and successful use of an old method of corrosion control has attracted the attention of the entire industry since its comparatively recent application to pipe lines. Corrosion engineers are now turning their attention to the corrosion and failure of gas- and oil-well casing due to electrolytic action. The protection of wells, however, creates another problem—that of providing protection for the lines themselves, which, prior to insulation, were protected at the expense of loss of metal from the well casing.



Enamel coating was applied to this coupling by a coating machine

Although corrosion engineers feel there is much yet to be learned concerning the inflow of currents to wells and the best methods of controlling the resulting corrosion, they are confident the insulating of lines near the wells will result in large savings to the industry.

Construction Methods Change

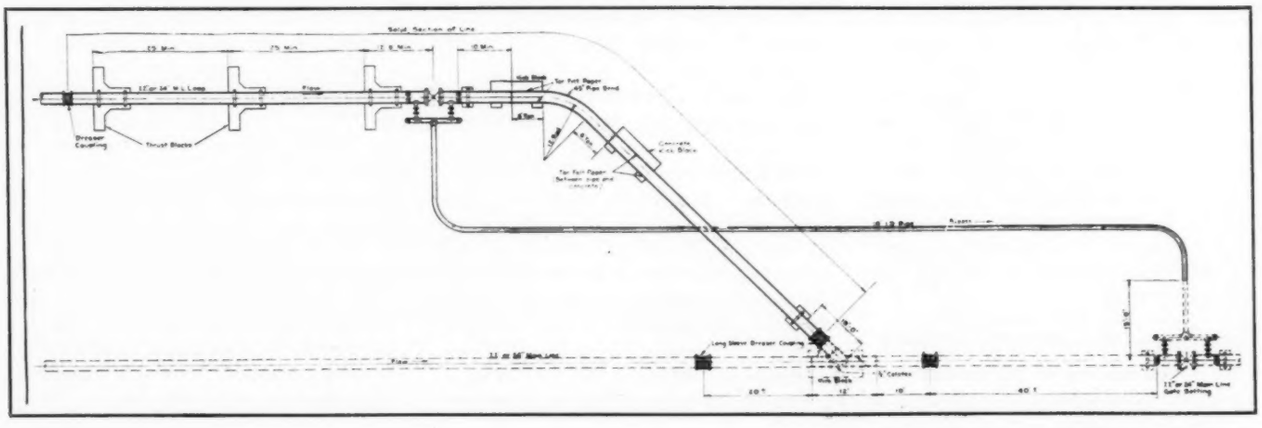
One of the more recent innovations in pipe-line design and construction, the use of streamlined connections, has been mentioned A more gradual tendency in design has been the use, on increasingly larger diameter lines, of continuous welded construction. Improvements in welding materials and application, which have made possible the production of welds as strong as or stronger than the pipe, have encouraged this trend. Simplifying the laying and painting of the line, this type of construction has many good as well as relatively unknown features.

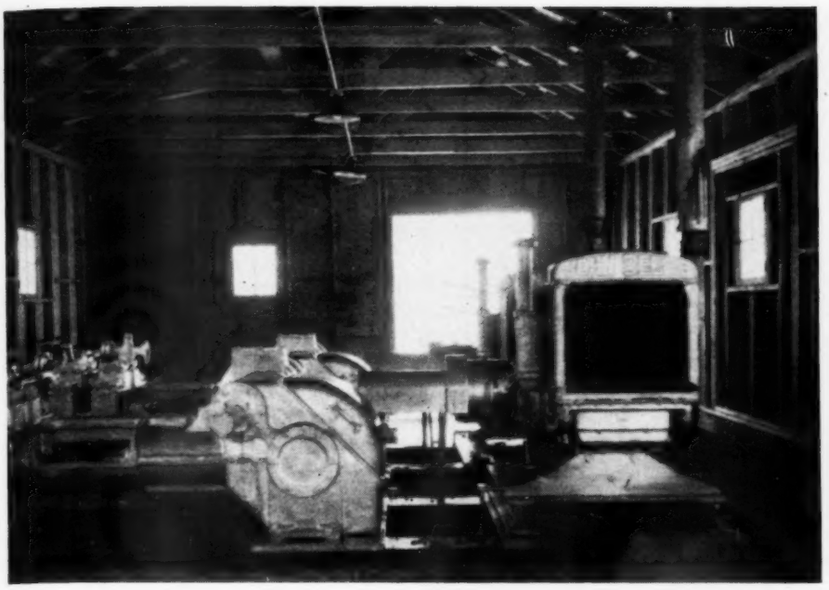
Last year saw an increasing use of a newly developed pipe-line coating machine. Similar to its predecessor, the pipe-cleaning and priming machine, it travels along the pipe line under its own power, balanced and held upright by its operating crew. Hot enamel from a supply tank, heated by two oil burners, flows around the pipe, being applied evenly to the desired thickness by circular spreaders. Excess enamel drains from the pipe, is caught in an open pan under the pipe, and returned by pumps to the supply tanks.

A new feature of the machine was used for the first time in January of this year, on a 24-in. gas line laid in Missouri. Hitherto, pipe-coating machines had been used principally on solid welded lines. On the very few coupled lines painted by the machine the coupled joints were coated by hand, the heavy machine propelling itself over the coupling on a track made of steel plate. On the line mentioned, however, couplings were coated in a specially designed form built into the machine. Guiding the machine in place over the coupling, the two halves of the hinged form were held tightly around the coupling, which was then covered thoroughly by the hot enamel.

Enamel used in the machine was the waterworks type, a coal tar product that remains slightly plastic under normal pipe-line operating temperatures. It was not necessary to add flux, even in coating the couplings, although the waterworks enamel was applied on several days when the temperature was 10° above zero.

This type of connection between loop and main line is designed to offer a minimum restriction to flow





Two units in series and a single unit used as suction pump. The two units in series, which can be placed in service simultaneously by use of small liners, deliver oil a distance of approximately 22 miles

A PETROLEUM ENGINEER FEATURE

Rapidly declining production requires judicious study to avoid costly errors in permanent pump station investment

Portable Pumps in Oil Pipe-Line Gathering Systems in Illinois Basin

By J. W. MEEHAN, Vice-President, Wabash Pipe Line Company; Superintendent, Illinois Division, Pure Oil Company

FEW divisions, if any, in the corporate setup of an oil company, enter into their functions with a scheme of organization so complete that subsequent growth will not require that some revisions be made.

The development of the Illinois Basin has brought to the attention of the pipe-line divisions of the various companies operating in the area several methods of handling production characterized by rather rapid decline following initial flush production.

In the spring of 1937, following the first few completions of wells in the Basin, one company decided to standardize by using similar power pumps driven by gas engines for all gathering operations. The topography of the east side of the Basin is such that a general gravity system is not practicable under most conditions. It was definitely ascertained in the beginning that it would be necessary to have an individual unit serve only two or three tank batteries. A portable unit was selected for the reason that this machinery would have to be quite flexible for general field operations. Another reason for using portable units was that permanent stations would not have to be built, thus avoiding the uncertainty of limestone production. Portable pumping equipment could be used in lieu of the erection of such pump stations, in any capacity desired, for these portable units could be hooked-up in series, the number depending upon the amount of flush production being handled in the various areas.

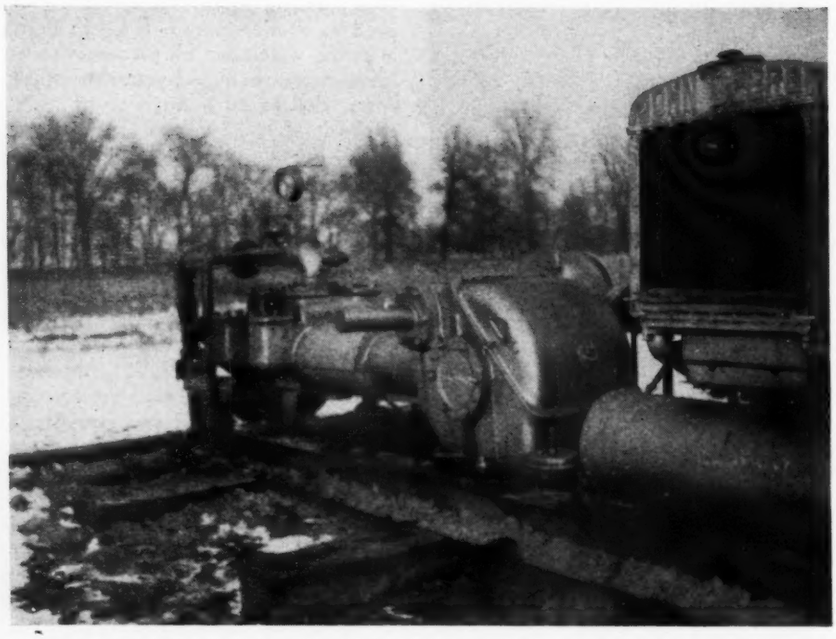
J. W. MEEHAN

joined the staff of The Pure Oil Company immediately upon completing his education at Northwestern University—His initial duties were in the purchasing and construction engineering departments—Later he was assigned to pipe-line construction work, then to operations in the Michigan Division—Was office manager of the latter when appointed superintendent of the Illinois Division in April, 1937—He is also vice-president of the Wabash Pipe Line Company, a Pure Oil Company subsidiary—His headquarters are in Olney, Illinois.

The type of power pump selected, therefore, would of necessity have to be flexible enough to handle a range of pressures that might be encountered, by having several units on a line at one time. For that reason, a 5 by 10 pump was selected in which the liners were interchangeable with small sizes down to and including 2½-in. liners. The pressure range available was from 250 lb. per sq. in. with the large liner to 1000 lb. per sq. in. with the 2½-in. liner. Of course, displacements were reduced accordingly as the liner size was reduced, and in several installations, it was necessary to install two or three units to handle production.

The accompanying table shows capacities and pressures that are available. A few pistons of each size are carried in the warehouse and such changes as are necessary can be made on short notice.

The choice of an engine to drive a pump such as described was a rather simple matter. It was apparent that there would be a range of pressures varying as to the length of lines and the number of units in operation at any one time. For that reason, a 40-hp. engine was selected, for it was apparent that in normal operations, the average horsepower required would be approximately 30. Horsepower requirements, however, vary from probably 5 to 40 due to operating conditions on various feeder lines.



A standard installation. Stub shaft of pump, fuel tank and regulator, and skid base set on timbers are discernible

Diameter of piston, in.	*Stroke, in.*	*Gal. per min.*	*Bbl. per hr.*	*R.p.m.*	*Maximum pressure, lb. per sq. in.*
2½	10	42.5	60	60	1000
3	10	65	92	60	700
4	10	122	174	60	400
4½	10	157	224	60	325
5	10	195	279	60	250

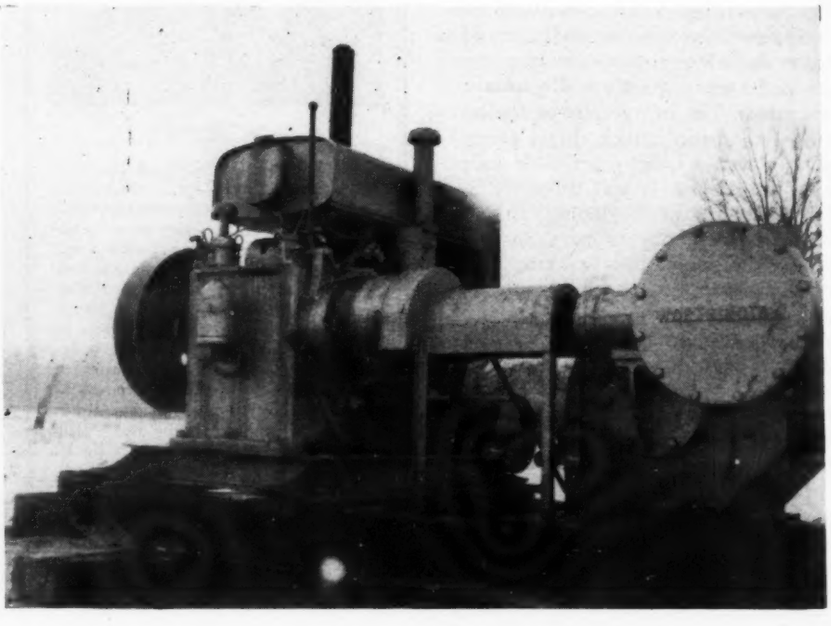
The unit now in use has been changed several times as to minor items of equipment but the two principal parts, namely the pump and engine, are still standard equipment.

A complete unit is assembled in the shop and all that is necessary after unloading at the location is the connection to suction and discharge lines. This complete unit consists of accessory equipment, including a standard bypass with a relief valve set at a pressure ranging from 275 to 700 lb. per sq. in., depending upon the area in which it is to be operated; a gas volume tank for use with natural gas; tool box with necessary emergency tools, and a fire extinguisher. The pump and engine are mounted on a manufactured steel base that is fabricated according to our own design and dimensions. The unit is dropped on timbers at the pumping site and this eliminates the need for a permanent foundation.

The original units were V-belt driven, but recently this method has been changed. The units now have a bevel gear drive. This drive is operated using two universal joints connecting the stub shaft of the engine direct to the pump shaft. This new method of drive provides better operation in that it is not necessary to provide take-up for belt adjustment. It is also a better method for year-around service in that, during extremely wet weather, there was a certain amount of slippage with the belt-driven units. This gear arrangement is totally enclosed for safety.

The unit can use as fuel either natural gas, gasoline, Diesel oil, or, in an emergency, crude oil. The latter is not too satisfactory for long term operation, due to its causing the formation of a large volume of carbon on cylinder walls and thinning of lubricating oil. Natural gas is used principally as a fuel and is delivered to the engine by either of two methods. One is by injecting it into the air stack and the other is by the use of a special carburetor (designed in the company's shop) in which the gas supply line is attached to the base of the carburetor; gas entering the bore of the carburetor then mixes with the air. The first method has no means of fuel-air mixture, and is entirely regulated by adjustment of a hand valve. The latter arrangement allows the carburetor to accommodate a fluctuating load without "hunting." This carburetor can be subjected to an apparent overload and will readily adjust itself to meet the load. There are no adjustments necessary on this part.

Several units in operation in the division have been in service daily since 1937. The average daily running time is about 10 hours. After about a year's operating time, the only repairs necessary consist of the installation of new rings and the grinding of valves in the engines. Repairs on the pumps are negligible. Protective maintenance, however, is responsible, no doubt, for such results. All units are inspected thoroughly each 60 days and such minor adjustments as are necessary are made to avoid serious breakdowns later on.



Bevel gear case and shaft connecting pump and engine are covered as shown for safety

JUST WHERE DOES LINK-BELT COME INTO THIS PICTURE?

ANY PIPELINER CAN TELL YOU

The investment in oil and gas pipe lines has long since passed the billion-dollar-mark . . . and the network, of necessity, keeps spreading. In equipment required to build and maintain this great transportation system there is nothing short of a fortune.

The oil industry doesn't quibble over the number of dollars involved in furthering its cause . . . but it weighs well the quality of the tools it uses to carry on. Names and brands wield unlimited influence with buyers . . . but only after the products they represent have proved true values through years of unfailing service.

We are justly proud of the reputation our products enjoy in the oil industry . . . Silverlink roller chains, for example, on ditching machines, pipe cleaning machines, pipe tongs, backfillers, power winches, hoists . . . Silverstreak silent chains in pump service on gathering lines and booster stations.

So fitting, in fact, is our place in this branch of the industry that every major pipe line project today employs, in one way or another, Link-Belt roller chain.

Link-Belt Company, Indianapolis, Dallas, Houston, Los Angeles, Philadelphia, Chicago, New York. Distributors in all fields.

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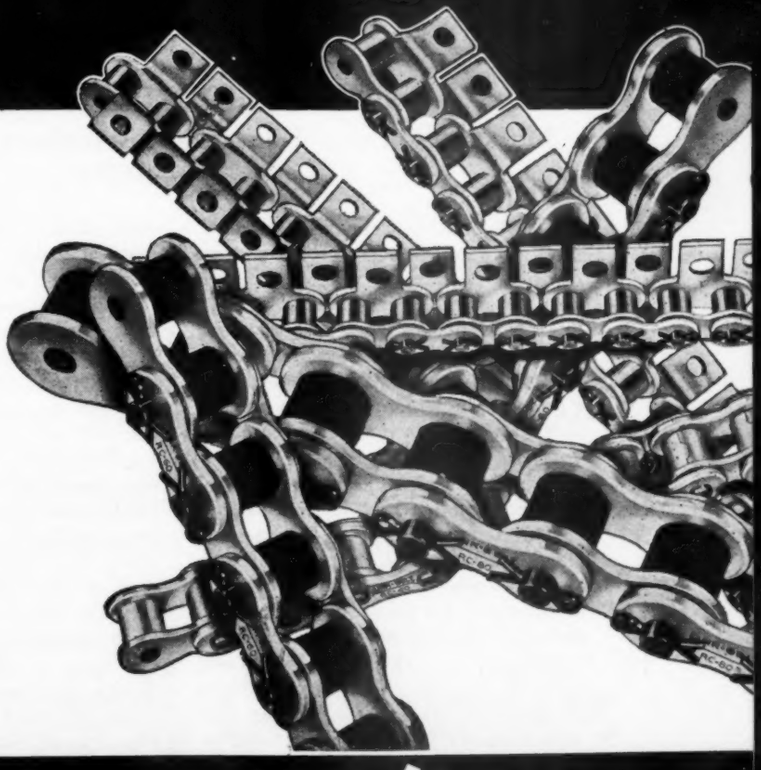
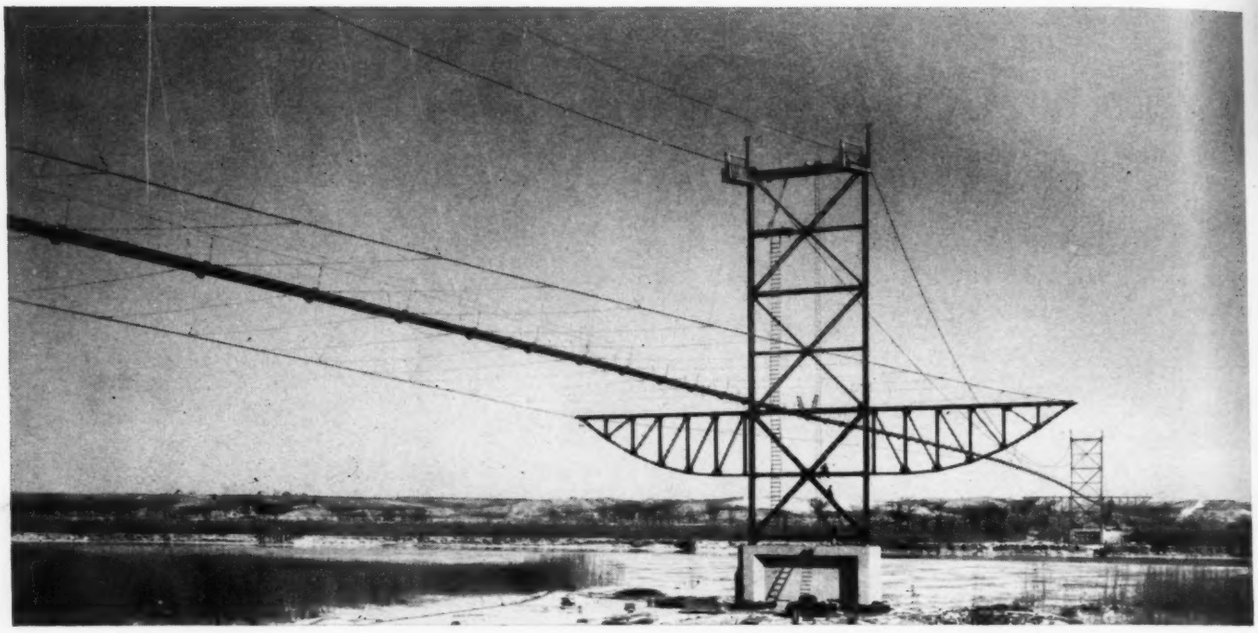


LINK-BELT *Silverlink* ROLLER CHAINS



General view of the bridge taken while under construction

Natural Gas Pipe-Line Suspension Bridge Over The Missouri River

Longest single-span pipe-line suspension bridge embodies newest engineering features of design and construction

By GORDON R. LUNT
Manager, Bridge Department, Pittsburgh-Des Moines Steel Company

GORDON R. LUNT

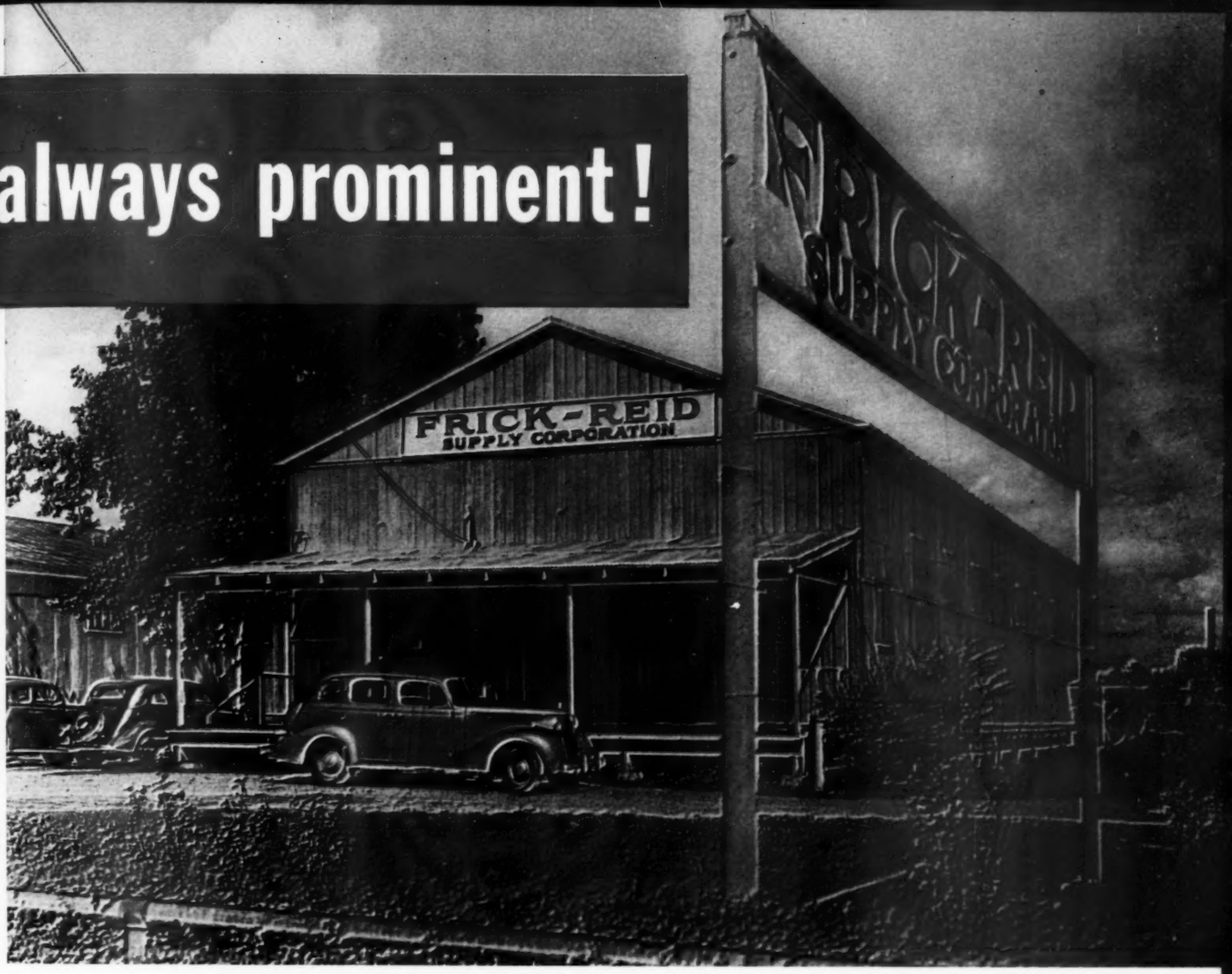
was graduated in engineering from the University of Iowa in 1921, and received his C.E. degree in 1927—Became associated with the Pittsburgh-Des Moines Steel Company, Des Moines, Iowa, in 1922, and has been manager of the Bridge Department since 1928—Has had ten years' experience in the development and construction of pipe-line suspension bridges.

NORTHERN Natural Gas Company of Omaha, Nebraska, confronted with the problem of crossing the Missouri River near Sioux City, Iowa, with its 16-in. pipe line, from South Sioux City, Nebraska, to Minneapolis, Minnesota, again decided on a pipe-line suspension bridge in preference to a submerged river crossing.

Matthews and Kenan, San Antonio, Texas, pioneer pipe-line bridge designers, were employed to design this important structure and the Pittsburgh-Des Moines Steel Company of Des Moines, Iowa, was given the contract to construct the bridge in its entirety and erect the pipe on the structure.

After an aerial survey had been made, to ascertain the approximate site of the bridge, four profiles were run approximately 350 ft. apart in order to procure the most suitable location. After the exact site had been decided on, preliminary designs and estimates were made to determine the most economical design to fit the chosen location. After a decision had been made as to the type and length of span, test borings were carried to a depth of 135 ft. below ground line at the location of each caisson of the main piers and one test hole to minus 75 ft. at each rest pier and anchor location. From the information thus obtained, the design was completed and the finished structure resulted in a bridge having a length of 3539.35 ft. face-to-face of concrete anchors, with a main channel span of 1320 ft. having a navigation clearance of 53.7 ft. minimum above U. S. Standard high water, and two side spans of 660 ft. each, making a total loaded length of bridge 2640 ft. center-to-center of rest towers, having two channel piers with footings 82 ft. below the accretion ground line. Each pier base consists of two steel caissons 13 ft. in diameter and 84 ft. deep, placed 36 ft. on centers. Resting upon these caissons are the 17 ft. high concrete pier tops, the shafts being octagonal in shape. Upon these rest the main towers, extending skyward 115 ft., with wind arms having a spread of

...always prominent!



A Frick-Reid Store in any field stands out in bold relief. It signifies service with a roof over it and a permanent address. It indicates the responsibilities of local investment and good citizenship, backed by the manufacturing and distributing facilities essential to the maintenance of seventy-five stores and twelve offices in old and new fields from the Atlantic seaboard to the Rocky Mountains and from the Gulf to the Great Lakes.

A Frick-Reid Store in any field is the symbol of economical and efficient buying on the part of operators who are themselves responsible, and who understand and respect the efficiency that necessitates investment in service facilities. A Frick-Reid Store is part and parcel of the long-range profit plans of the oil industry, for the industry knows that Frick-Reid equipment will never be orphaned or Frick-Reid leadership abandoned anywhere.

FRICK-REID *Supply Corporation*

TULSA, OKLAHOMA

75 STORES AND 12 OFFICES IN OLD AND NEW FIELDS

156 ft. center-to-center of wind cables. Back 660 ft. from the center line of the main piers are situated the concrete rest piers, founded on steel bearing piles. These serve to support the rest towers that rise 50 ft. above the top of the piers. Back from the center lines of the rest towers are the main anchors, 454.05 ft. on the Iowa side and 445.90 ft. on the Nebraska side, each 40 ft. long by 16 ft. wide and 16 ft. deep, founded on steel sheet piles that are electrically welded to the steel wales embedded in the concrete, making the steel sheet piles serve a dual purpose; namely, acting as bearing piles and affording protection against possible scour.

Extending from the compact anchorages at the main anchors over the tops of the rest and main towers are the two main cables, each consisting of seven 1⅛-in. diameter galvanized bridge strand served together with No. 10 galvanized wire. Attached to these cables are the main cable suspender system and cradles that support the pipe, which is laterally supported by two 2¼-in. wind cables in conjunction with the wind cable suspender system.

Actual construction began September 19, 1939, all concrete work was completed by December 9, 1939, and the pipe erection was completed February 4, 1940; a total elapsed time of 140 calendar days, or 135 actual work days. After December 23 extremely severe weather was encountered, with temperatures as great as 22° below zero, which retarded the cable and pipe erection to a considerable extent.

The construction of the concrete anchors and rest piers involved the normal type of equipment and procedure, whereas the work involved in the erection of the towers, cable, and pipe called for considerable ingenuity, special methods, and equipment, which have been developed through years of experience in this special type of construction.

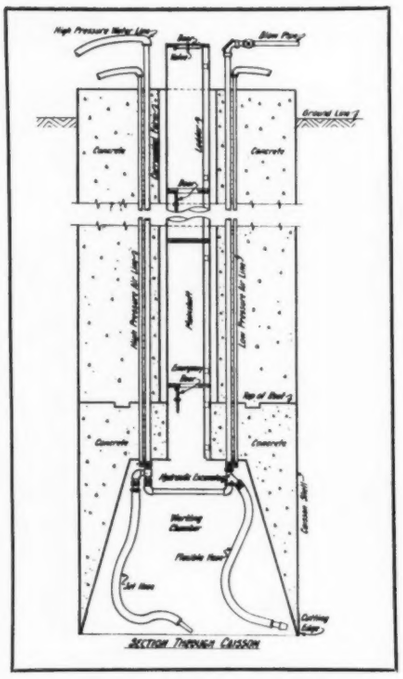


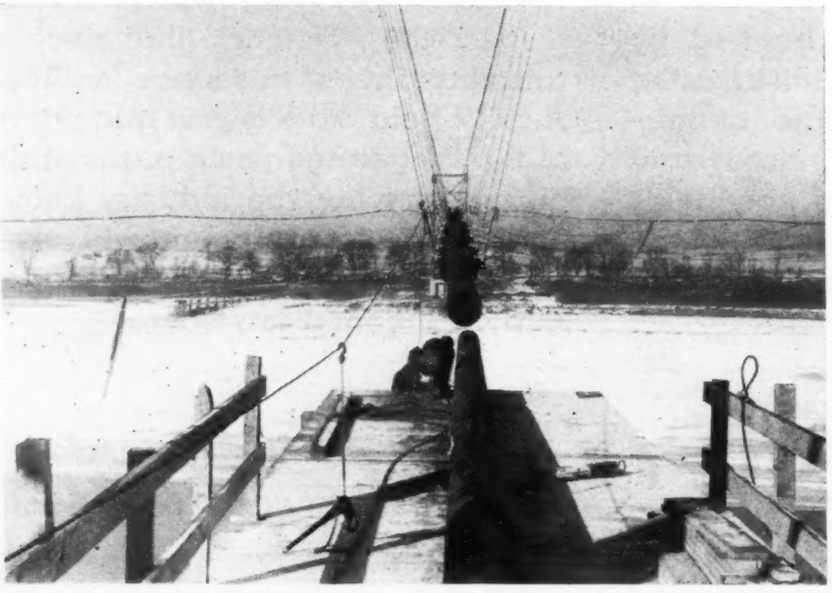
Fig. 1. Schematic drawing showing principal parts of the pneumatic caisson

As the sinking of the main pier caissons presented construction problems requiring skilled direction of numerous pieces of suitable equipment adapted to this particular type of work, a brief discussion will be made of this phase of the construction.

The English word "caisson" has been derived from the French word meaning "box," and very often workmen employed in this type of construction refer to the caisson as the "box." The principal parts of the pneumatic caissons used on this particular job are shown schematically in Fig. 1. These consist of an air-tight working chamber with its enclosing walls and roof and the cutting edge at the bottom. The roof is penetrated by the air and water pipes and the 36-in. diameter main shaft which, in this particular case, was used both as a material and main shaft. It is through this shaft that the workmen go to and from the working chamber. The shaft was also used for the removal of logs and boulders encountered that were too large to pass through the blow-pipe; also upon completion of the sinking of the caissons, concrete for the sealing of the working chamber was "ridden through" this shaft by the "sand hogs." It will be noted that a section of the main shaft was cast in the roof concrete of the working chamber; to this section was added 10-ft. sections of main shaft as the sinking progressed.

A 4-ft. diameter corrugated inside form was left in place, which permitted the removal of the main shaft above the 5-ft. section embedded in the roof concrete.

To the top diaphragm plate of the two top sections of the main shaft are attached the doors, each equipped with a rubber gasket that comes in bearing with the milled inside surface of the diaphragm plate of each main shaft, and each door is equipped with a valve. As the sinking progressed, additional doors were added, to be used in case of a "blow-out." To permit entrance of workmen into the working chamber, with the pressure on, the upper door and valve of the second section of the main shaft is necessarily closed, with the valve lever on the upper side of the door. The men enter the top section of the main shaft at atmospheric pressure, then the top door and valve, with valve lever on the inside, are closed and the door is held in place by the "lock tender." Then the valve of the upper door of the second main shaft is opened and the air rushes violently in with a loud hissing noise. To some it produces a disagreeable effect, like that of water filling the ears, which can be relieved by tightly pinching the nostrils, then trying to expel air from the lungs through them, and repeatedly swallowing. As soon as the pressure has



Erecting pipe

NEWS FROM THE "FIRING LINE"

BITUMASTIC 70-B Enamel

was used to protect the entire 242 miles of 16-inch pipe laid for Northern Natural Gas Company between Sioux City, Iowa and Minneapolis.

Many successive Bitumastic coating jobs for the Northern Natural Gas Co. culminated in an order for Bitumastic 70-B Enamel Coating for this 242-mile stretch of 16" pipe . . . the longest natural gas trunk line laid for many years! It's a tribute to the effectiveness of Bitumastic Coating for protecting oil and gas pipe lines.

On this particular job, the pipe was machine-coated with Bitumastic 70-B Enamel applied simultaneously with 80-pound kraft paper bonded to the enamel and an unbonded wrapping of asbestos pipe line felt.

Bitumastic has been protecting pipe and other structures for well over a half-century in all parts of the world. No other pipe coating material has been in use as long; no other equals its performance record. There is no substitute for experience—which means no substitute for genuine Bitumastic.

BITUMASTIC

No other pipe coating material has been in use as long. No other equals its performance record.

●

Bitumastic 70-B Enamel—the ideal coating material for buried oil and gas lines—provides the following advantages over ordinary coal tar coatings:

- ★ Better flexibility
- ★ Better adhesion
- ★ Greater resistance to expansion and contraction
- ★ Exceptional resistance to soil stresses
- ★ Greater ability to withstand handling abuse
- ★ Time-proved ability to withstand corrosion

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WESTFIELD, NEW JERSEY

become equalized with that in the remaining main shaft that connects to the working chamber, the bottom door is opened and the workmen descend by ladders to the working chamber where the "sand hogs" work. Working time in this chamber varies from two 4-hour shifts per day to a minimum of two 3-hour shifts per day under pressure of 45-50 lb.

As the caisson is buoyed by a force equal to the weight of the water displaced, less the weight of the caisson and skin friction, it is necessary to keep adding weight to the caisson as the sinking progresses. This is done by pouring concrete between the caisson shell and the inside form. On two of the caissons it was necessary to add about 150-tons additional weight in order to overcome the friction—it was also necessary to "blow" the caissons frequently, which means to reduce the air pressure suddenly by several pounds. The reduction in pressure, if the caissons are heavy enough, will cause them to sink.

The air pressure required increases as the sinking progresses. Consequently the compressor plant must be designed to provide the maximum air pressure required, and this is equal to the vertical hydrostatic head above the cutting edge, divided by 2.3 ft. per lb. pressure. The pressure computed in this way is increased 10 percent to take care of any increased pressure required to seal the working chamber, and to this is added the drop in pressure due to friction loss in the low-pressure pipe line, which runs from the low-pressure air receiver to the working chamber.

As there is always a leakage of air through the door and shaft gaskets, and under the cutting edge, ample capacity of air at the required pressure must be provided. The amount varies considerably, the porosity of the material encountered being a big factor, whereas the area of the working chamber does not influence the rate of leakage so much as the linear length of the total cutting edge.

The approximate average quantity of actual air required is computed by using the formula:

$$V = 0.15\,P + 4.25$$

where

V = cu. ft. of actual free air per ft. of cutting edge

P = maximum pressure, lb. per sq. in. gauge

The actual volume of the free air computed by the above formula is divided by the volumetric efficiency of the air compressor to obtain the capacity of the compressor plant.

The compressor plant consisted of two units. One unit was capable of producing 710 cu. ft. of air at 55 lb. and, by changing three valves, capable of producing 550 cu. ft. at 125 lb. The other unit had a capacity of 738 cu. ft. at 55 lb. The low-pressure air lines of both compressors were connected to a 265-cu. ft. air receiver to which was attached the low-pressure air line of the caissons and the air line of the "hospital lock," which was used in case of the "bends" and was situated in the "sand hog" house; also a high-pressure air line was run from the high-pressure air receiver of one compressor to the caissons.

To begin the sinking of a caisson, a hydraulic excavator was used inside the working chamber and no air was employed until the water level was reached. This excavator was actuated by water rushing past the jet at a high pressure, which, in this case, was supplied by a 5-stage centrifugal pump powered by a 125-hp. engine capable of pumping 500 gal. of water per minute at 250-lb. pressure. The materials encountered were jetted with a high-pressure water jet and then sucked up through the flexible hose and carried by the water to the outside through the blowpipe. After the air pressure reached a pressure of 18-20 lb. the hydraulic excavator was removed and the materials that would enter the opening of the flexible hose were forced by the air, aided by water, from the working chamber through the flexible hose and blowpipe to the outside. When hard materials were encountered that could not be cut with the high-pressure water jet, paving breakers, air spades, and picks were used to reduce the materials to workable sizes.

After each caisson was sunk to grade, the working chambers were sealed-off with concrete, this being done by "riding it through," which, with some modifications, is identical to the method employed in taking workmen in and out of a caisson.

After the sealing was completed, the necessary air pressure was maintained until the concrete had set sufficiently to permit safe removal of the air. The main shaft was then removed, after which the well was filled above the top of the caisson roof to a distance of 11 ft. 6 in. After both caissons of each pier were sealed-off and the wells filled to grade at their bases, each well was closed-off 15 ft. below the top of each caisson and the web wall forms constructed. Then the two wells, web wall, and the caisson top course were poured monolithically, which formed the pier base upon which was constructed the pier top.

"Sand hogs" in working chamber under 30-lb. air pressure

It may prove of interest to some to know that in the construction of the bridge, the following quantities were involved: Concrete, 2730 cu. yd.; structural steel and castings, 468 tons; permanent cable, 18.14 miles, and No. 10 galvanized wire, 15.5 miles (for serving the main cable).

All structural steel involved was fabricated at the contractor's plant at Des Moines, Iowa; all cable was manufactured by John A. Roebling's Sons Company, Trenton, New Jersey, and cable engineering was by Matthews and Kenan. The construction of this bridge was under the direction of the writer of this article. J. V. Blake was construction engineer, D. W. Hedrick, superintendent of pneumatic caisson work, L. H. Heidbreder, superintendent on the construction of the anchors, rest piers, and the erection of the structural steel, cable, and pipe, and the owners were represented by Ross N. Cox, who served in the capacity of field engineer and inspector.

This structure is the longest single span pipe-line suspension bridge known and has embodied in its design and construction all the newest features developed through years of intensive study and experience in this peculiar and difficult type of design and construction. The writer feels confident that, in the near future, natural gas will be safely carried across the Mississippi River by use of natural gas pipe-line suspension bridges.

Control the Pipe-line Flow

With these General Electric Motors

WHETHER you plan to install centrifugal or reciprocating pumps—or both—in your pipe-line pumping stations, General Electric can supply the types of motors and control in the sizes you need to operate with economical use of power.

A large pipe-line company recently found it profitable to use all of the three types of motors shown here. It wanted to pump gasoline at varying rates over its main line, yet allow for the use of many outlet lines. And it wanted to keep its control as simple as possible.

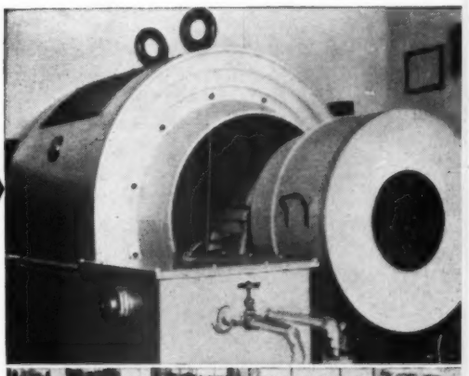
G-E engineers helped solve this problem by devising a system employing these three types of motors, with control so simple that it could be handled by unskilled operators.

What was done for this company can be done for you. Whatever your pipe-line pumping needs, consult your nearest G-E representative, or write General Electric, Schenectady, N. Y.

HIGH-SPEED WOUND-ROTOR MOTOR

Here's a G-E high-speed wound-rotor induction motor connected to a centrifugal pipe-line pump in Pennsylvania. Its speed can be varied to change the rate of pumping. General Electric pioneered in the application of this type of motor to pipe-line pumping service.

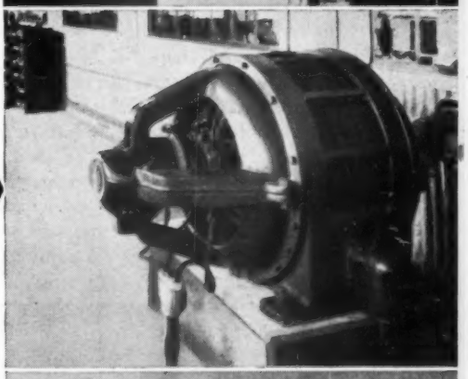
G-E 600-hp 3600-rpm motor



LOW-SPEED WOUND-ROTOR MOTOR

This G-E low-speed wound-rotor motor, shown driving a 15,000-barrel pump in an Oklahoma pumping station, provides the advantages of electric drive for reciprocating pipe-line pumps. It has the high starting torque and variable speed required to drive this type of pump at varying rates of flow.

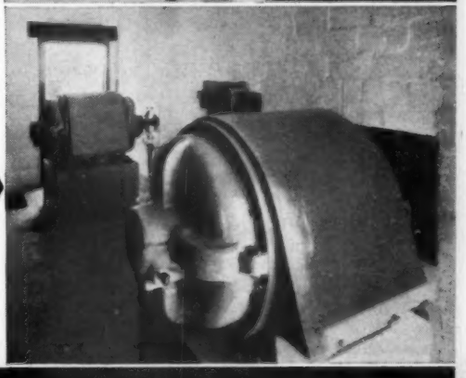
G-E 200-hp 450-rpm motor



HIGH-SPEED SQUIRREL-CAGE MOTOR

This G-E high-speed squirrel-cage induction motor, one of the most popular G-E motors for pipe-line pumping, has many distinctive features, including axial-rotor ventilation to reduce windage noises, and non-wearing air seals to maintain effective lubrication. In this picture, two of them are coupled through a fire wall to centrifugal pumps in a Texas installation.

G-E 350-hp 3600-rpm motors



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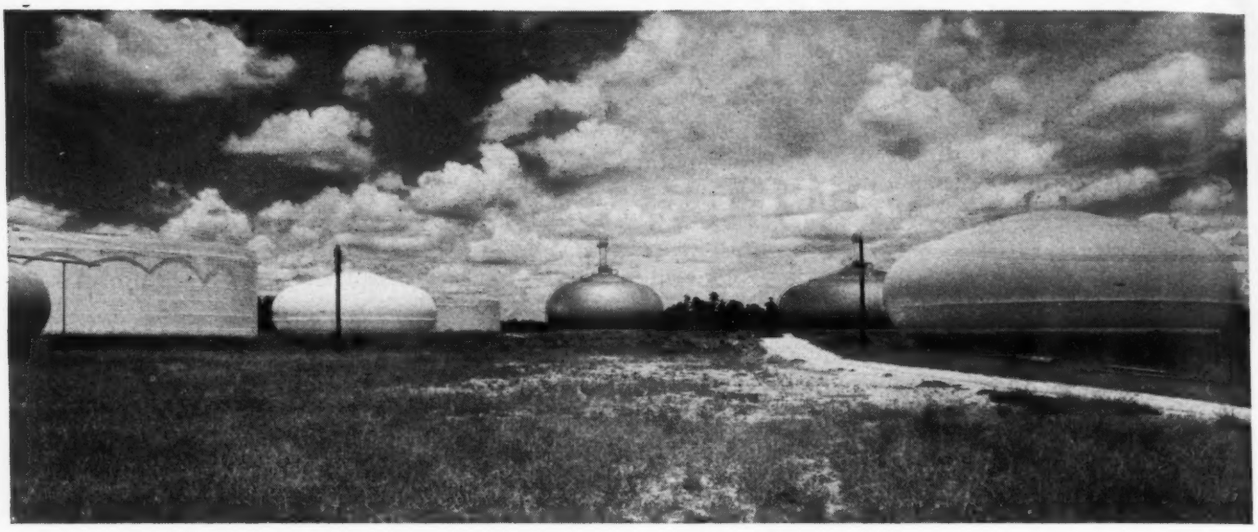


Fig. 1. A group of large Hortonspheroids

Streamlined Pressure Vessels Solve Petroleum Industry's Newest Storage Problems

Use of spheroid tanks makes possible the transportation of volatile liquid products without change in their quality or loss of volume

By D. E. LARSON

Development Engineer, Chicago Bridge and Iron Company

THE clusters of tomato-shaped storage tanks blossoming forth at refineries and terminals throughout the world have aroused widespread curiosity and there has been much speculation regarding the origin and use of this type of vessel, which is known as the Hortonspheroid. The name is derived from that of the inventor who pioneered its development, George T. Horton, and from its characteristic shape, which is defined by the word spheroid, meaning "a solid of revolution formed by rotating an ellipse about one of its axes"; in this case, the minor axis.

Economy demands that volatile liquid products be transported and marketed without change in quality or loss in volume. An ideal way to accomplish this would be to handle such products in hermetically sealed containers. Although this is impractical in large scale operations for perfectly obvious reasons, the petroleum engineer has long dreamed of its practical equivalent; namely, transporting light products through pipe lines and storing them in huge pressure vessels at the pipe-line stations and terminals. This dream has become a reality with the advent of gasoline pipe lines and the development of the Hortonspheroid, a pressure vessel that can be constructed economically in units of any desired capacity.

D. E. LARSON

graduated from Oregon State College in 1928 with a bachelor's degree in civil engineering—Was research graduate assistant in the engineering experiment station at the University of Illinois, 1928-30, where he majored in structural engineering and was granted a master's degree —In 1930 was employed by the Chicago Bridge and Iron Company where he served as assistant engineer in the research department and consultant on technical sales problems in the sales department—At present is development engineer in charge of development activities for the company.

The spheroid represents the modern version of the volatile product tank. Its contours have been gently rounded to provide uniform stress paths in much the same manner that other objects have been streamlined to decrease air resistance. The basic idea underlying the spheroid is not new. It was conceived many years ago. The first units were built in 1928 employing riveted construction throughout. At that time there was no great demand for pressure storage. Only a few units were placed in service each year for some years thereafter. In 1935, however, the installation of pressure storage units took a marked upturn. The combined capacity of all Hortonspheroids placed in service that year amounted to more than 500,000 bbl. By 1937, this figure had increased to 3,400,000 bbl. This remarkable increase in the use of pressure storage was the result of concurrent developments in several different fields. A typical group of large Hortonspheroids is shown in Fig. 1.

In the petroleum industry, the development of new processes and products created a demand for vessels capable of storing large volumes of premium grade products without deterioration or loss by evaporation. About

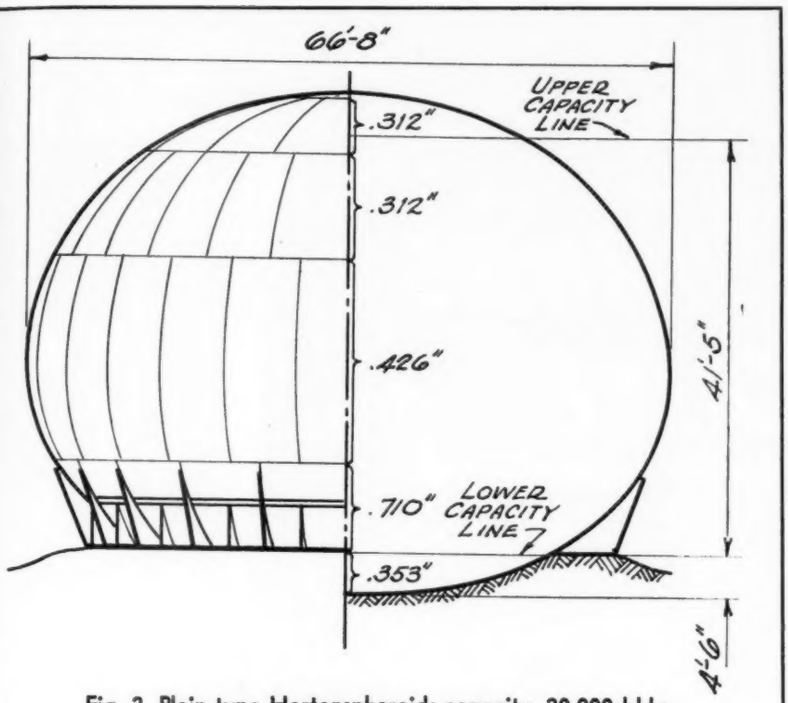


Fig. 2. Plain type Hortonspheroid; capacity, 20,000 bbl.; working pressure, 15 lb. per sq. in.

the same time, certain improvements in design made it feasible to construct spheroids in much larger sizes than was previously thought possible. Coupled with this, certain advances in methods of fabrication and erection helped to reduce costs to a point where the purchase of pressure storage could easily be justified by the results achieved. In short, pressure vessels of large capacity became commercially available at about the time a demand for them began to exist.

The phenomenal growth of the natural gasoline industry is one of the developments that created a new demand for efficient storage vessels. Natural gasoline is used primarily as a blending agent in the production of high-quality motor fuels. Although its production normally continues at a fairly constant rate throughout the year, the peak demand occurs in the Fall when stocks of gasoline are blended for winter consumption. This means that hundreds of thousands of barrels must be accumulated in storage to meet seasonal demands. The vapor pressure of natural gasoline is much higher than that of straight-run gasoline. This quality imparts to the blend the easy starting properties so vital to a winter motor fuel. Unfortunately, the ready tendency to vaporize also causes enormous evaporation losses during the summer storage period unless special precautions are observed. On warm days, natural gasoline stored in an ordinary cylindrical tank simply boils away at a rate depending on the amount of heat it receives from the atmosphere.

Evaporation losses from natural gasolines can be prevented either by the installation of a refrigeration system or by the use of pressure storage. In the first method, the tanks are insulated to reduce the absorption of heat, thereby reducing the quantity of vapor evolved, and the vapors are collected through a system of vapor lines and condensed into liquid by a process of compression and cooling. This method has been used with fair success in refineries but it is not well adapted to terminals where a limited operating personnel is available. The second method consists of storing the product in vessels designed to withstand internal pressure. In this case, the formation of vapor merely causes an increase in the vapor space pressure and the vapors are not displaced from the tank or lost. This method is now used almost universally. Pressure vessels function automatically without the services of an attendant and are, therefore, subject to no operating expense other than ordinary maintenance.

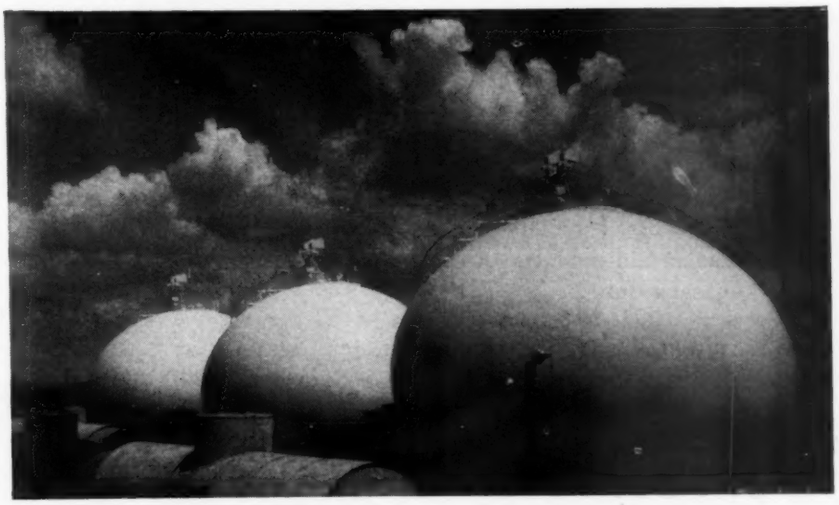
To illustrate the factors involved in the selection of a suitable vessel for the storage of natural gasoline, let us suppose we require storage facilities for 20,000 bbl. of 26-lb. Reid vapor pressure natural gasoline in a locality where the temperature of the surface of the stored liquid may be expected to reach a maximum of 105° F. The problem is to obtain the most economical pressure vessel that can be designed to meet the given operating conditions. A 26-lb. R.V.P. gasoline has a true vapor pressure of approximately 29.0 lb. per. sq. in. abs. at 105° F. Deducting atmospheric pressure, 14.7 lb., we find the required operating pressure for the vessel to be 14.3 lb. per sq. in. gauge. A vessel designed for 15 lb. working pressure may be used.

Design of Vessel

The next step is to design the vessel. In doing this we may take advantage of the fact that a steel plate can be stressed in more than one direction without any decrease in its strength. By making the entire shell of double curved plates every pound of steel can be utilized at maximum efficiency in resisting stresses in two directions. The

(Continued on Page 130)

Fig. 3. Three 7500-bbl. Hortonspheroids in natural gasoline service



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ANOTHER ***first*** The Cummins Diesel is the first diesel among fleet operators, from coast-to-coast, who now have combined mileages of more than 150,000,000 miles on their Cummins Diesel-powered trucks.

ANOTHER ***first*** The Cummins Diesel was the first diesel to demonstrate its economy on BOTH long and short hauls . . . an all-over economy that includes not only more miles per

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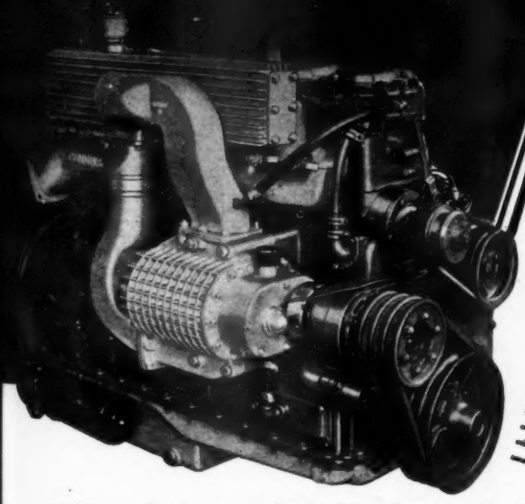

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HE *first* DIESEL IN VALUE AND PROVED PERFORMANCE?

(Continued from Page 127)

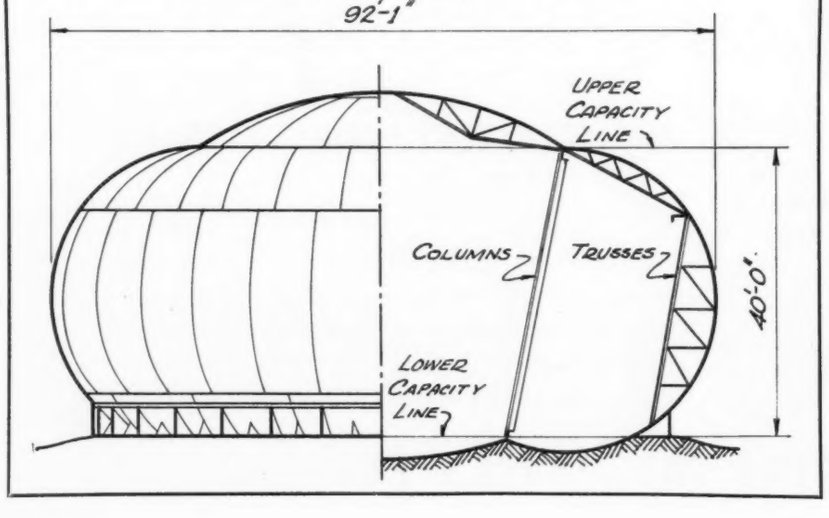
most economical design will be one in which the principal stresses due to combined liquid and gas loads are equal at all points in the shell, thereby making it possible to use a shell plate of uniform thickness. This can be accomplished by laying the shell out to a certain curve, which depends on the volume of liquid to be stored, its weight, and the working gas pressure. In this way, we arrive at the design of the 20,000-bbl., 15-lb. Hortonspheroid shown in Fig. 2. If the shell of this vessel were always subject to the full liquid load and the full working gas pressure of 15 lb. per sq. in., the entire shell, including the bottom, would have a thickness of approximately 5/16 in. It must be designed, however, to withstand all possible combinations of liquid and gas loads, thus necessitating the use of heavier plates in the lower portion of the shell where the stresses, due to liquid alone, are greater than those resulting from combined liquid and gas loads. The spheroid is equipped with an outside base girder that transmits the load of the liquid in the overhanging portion to the soil upon which the structure rests. The vessel contains no internal bracing or framing of any kind. Spheroids of this type are called plain spheroids to distinguish them from the type known as the noded spheroid, a later modification. A group of plain spheroids in natural gasoline service is shown in Fig. 3.

As mentioned, the shape of the curve depends upon the volume of liquid, its weight, and the working pressure. This means that for a given liquid weight and working pressure the plain spheroid has a fairly constant ratio between height and diameter. When the capacity is increased, the height increases in proportion to the diameter. This consideration limits the capacity that may be provided in a single unit to about 30,000 or 40,000 bbl. A 40,000-bbl. plain spheroid has a total liquid depth of about 50 ft. Soil conditions at most of the sites where tanks are built will not support liquid heads in excess of 50 ft.

Fortunately, recent developments in the design of spheroids have made it possible to provide more than 40,000 bbl. in a single unit by modifying the construction to limit the height without sacrificing other economical features. This is accomplished by flattening the vessel and introducing a series of internal tension members to make it retain this flattened shape when subjected to gas pressure. The construction employed for this purpose is illustrated in Fig. 4, which shows the outline of a 40,000-bbl. Hortonspheroid of the noded type. The outer shell has the shape of a torus whereas the roof and bottom at the center are portions of true spheres. A circular girder attached to the roof plates along the cusp formed by the intersection of the torus and the center dome is connected to a corresponding girder at the bottom by a series of sloping structural members. These members serve both as tension ties to resist gas pressure and as columns to support roof loads and resist vacuum.

The trusses attached to the outer shell are not a vital part of the structure. They could be omitted by increasing the thickness of the plates in certain areas, particularly the lower part of the shell. Nevertheless, a very definite economy is effected by the use of these trusses. In the first place, they serve as an erection frame-work, thus eliminating the need for temporary scaffolding. In the second place, they help to support the liquid in the overhanging portion, thereby creating a more uniform distribution of resisting stress in the shell itself. As a result, the thickness of the shell plate from top to bottom is more nearly uniform than would otherwise be the case. The vertical reaction at the bottom of these trusses is applied to the foundation through an outside bearing girder similar to that used on the plain type of spheroid.

Fig. 4. 40,000-bbl. noded type Hortonspheroid



The outstanding feature of the noded spheroid as compared to the plain type of spheroid is the ease with which its dimensions can be varied to meet a set of given conditions. For example, the noded spheroid in Fig. 4 has a height between capacity lines of 40 ft., and a diameter of 92 ft. 1 in. If soil conditions at the place of installation had not permitted a 40-ft. liquid depth, the height could have been reduced by decreasing the radius of the outer torus curve and increasing the diameter of the spheroid to provide the same capacity. Furthermore, the diameter and capacity of a noded type spheroid having a given liquid height, may be increased almost indefinitely by adding more nodes between the outer torus and the center dome. An 80,000-bbl., 10-lb. Hortonspheroid has one intermediate node and a 100,000-bbl. unit has two. These vessels have been constructed in capacities to 100,000 bbl. and much larger units are feasible. A 100,000-bbl. Hortonspheroid with two intermediate nodes is illustrated in Fig. 5.

Lower costs resulting from improved methods of fabrication and erection have also played an important part in extending the use of pressure storage. The most outstanding step has been the change from riveted to welded construction. Welded seams eliminate the heavy butt straps required for the shells of riveted vessels. This effects an appreciable reduction in the total weight of steel and a corresponding reduction in cost. Furthermore, the details of construction in a welded container are less complicated than those in a riveted vessels. As a result less work is required in the drafting room and the shop, and the cost is reduced proportionately.

The welded vessel also enjoys a distinct advantage from the standpoint of seam tightness. The tightness of the seams in a riveted vessel depends on the accuracy of fabrication and the care used in fitting up the steel and caulking the plate edges and rivet heads. Although a riveted vessel may be perfectly tight at the time of completion, there is always the possibility that a few leaks may develop at a later date. Such leaks in light product tanks are sometimes responsible for large unsuspected losses because they are not read-

ily detected. The liquid vaporizes as fast as it seeps through, leaving no visible discoloration on the tank shell. Welded joints properly executed are less subject to troubles of this sort. A welded joint that is initially tight may reasonably be expected to remain so throughout the useful life of the vessel.

The use of welding for field-erected pressure containers introduced some new difficulties that had to be overcome before the process could be looked upon as a completely successful venture. Foremost among these was the problem of shrinkage. The contraction in the welded seam and the adjacent plate due to cooling of the molten metal is sure to cause severe distortions in the shell unless a carefully regulated welding sequence is observed. Distortions from shrinkage are prevented by keying all plates in the structure together in place before beginning to weld and then following a welding sequence calculated to hold contraction to a minimum. The key equipment is adjusted to relieve strains as the welding progresses.

The third and youngest of the spheroid family is shown in Fig. 6. It is called the Hemispheroid. The similarity to the noded type of Hortonspheroid is at once apparent, the principal difference being that the outer shell consists of a cylinder instead of a torus.

Strict economy in pressure vessel design results from the diligent application of two principles:

(1) Using all material in the shell, roof, and bottom to resist stresses in two directions.

(2) Designing all internal members to serve two or more functions; e.g., the use of columns to resist roof loads in compression and gas pressure in tension.

The Hemispheroid violates the first of these in having a cylindrical shell that is stressed by liquid in the circumferential direction only. The economical use of this vessel is thus limited to small capacities when the minimum plate thicknesses are greater than thicknesses required for stress, thus making it possible to use a cylindrical shell without a severe penalty in the form of added shell material. Hemispheroids are constructed in capacities to about 30,000 bbl. and for relatively low operating pressures ranging from 2½ to 5 lb. per sq. in.

Although several million barrels of Hortonspheroid storage has been installed for natural gasoline service, the vessel's use is not limited to this particular field. Pressure storage provides a practical solution to almost any problem involving the storage of a fairly large quantity of volatile liquid without loss of volume by evaporation or change in physical properties. A demand for storage facilities has also arisen from the rapidly increasing use of 100-octane aviation gasoline and other fuels of premium grade. Such products can be stored indefinitely in a pressure container without any decrease in octane rating or other deleterious effects. Motor fuels within the ordinary boiling range can be stored without loss in vessels having a working pressure of 2½ lb. per sq. in. The Hemispheroid with cylindrical shell is used quite extensively for this service in units having capacities to about 30,000 bbl.; 2½-in. Hortonspheroids of the noded type are used for greater capacities.

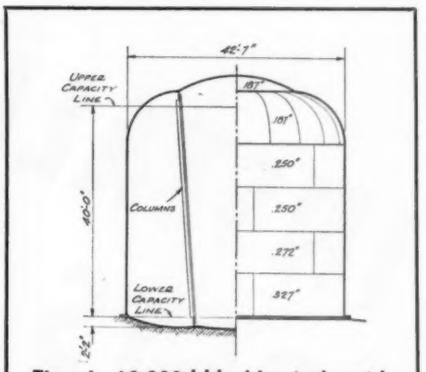
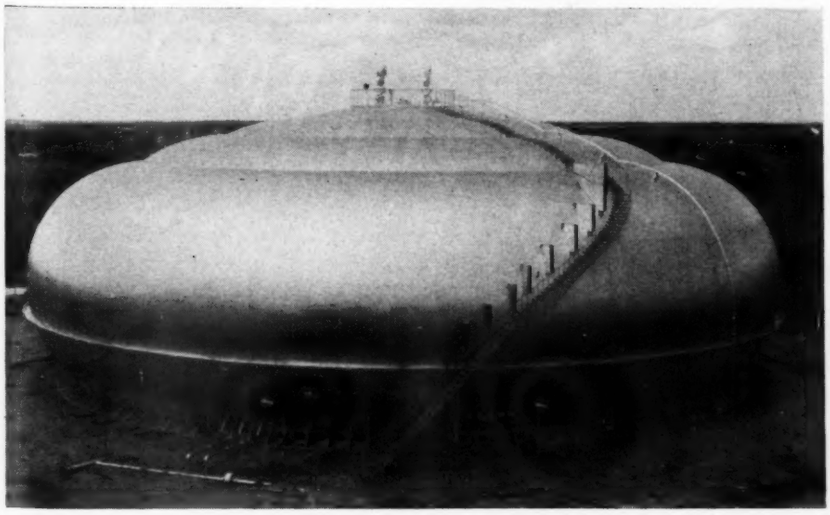


Fig. 6. 10,000-bbl. Hemispheroid; working pressure, 2½ lb. per sq. in.

Generally speaking, almost every improvement that has been made in storage containers for the purpose of reducing evaporation losses, has also tended to decrease fire hazard. This statement applies to all types of pressure vessels. If the working pressure is properly chosen there will be no venting whatever during periods of standing storage and, as a result, no possibility of ignition in the vapor space from outside sources. Explosive vapors on the outside of the vessel are also eliminated. The danger of an explosion inside the vessel from any source whatsoever is also greatly minimized by the fact that the vapor space mixture normally has a degree of saturation far above the explosive range.

In earlier years, attempts to arrest loss by evaporation were hindered by the intangible aspect of the loss. Many operators were uncertain regarding the magnitude of such losses and others claimed not to have any. The petroleum industry, as a whole, is now thoroughly aroused to the loss of profit accruing from evaporation loss and is making a determined effort to eradicate this evil. In a pressure vessel it is a simple matter to keep a record giving some idea of its efficiency. A seven-day pressure recorder attached to a connection into the vapor space will provide a permanent chart showing the pressure in the vessel at all times during its operation and will indicate when venting occurs and for what periods of time.

Fig. 5. 100,000-bbl. Hortonspheroid with two intermediate nodes



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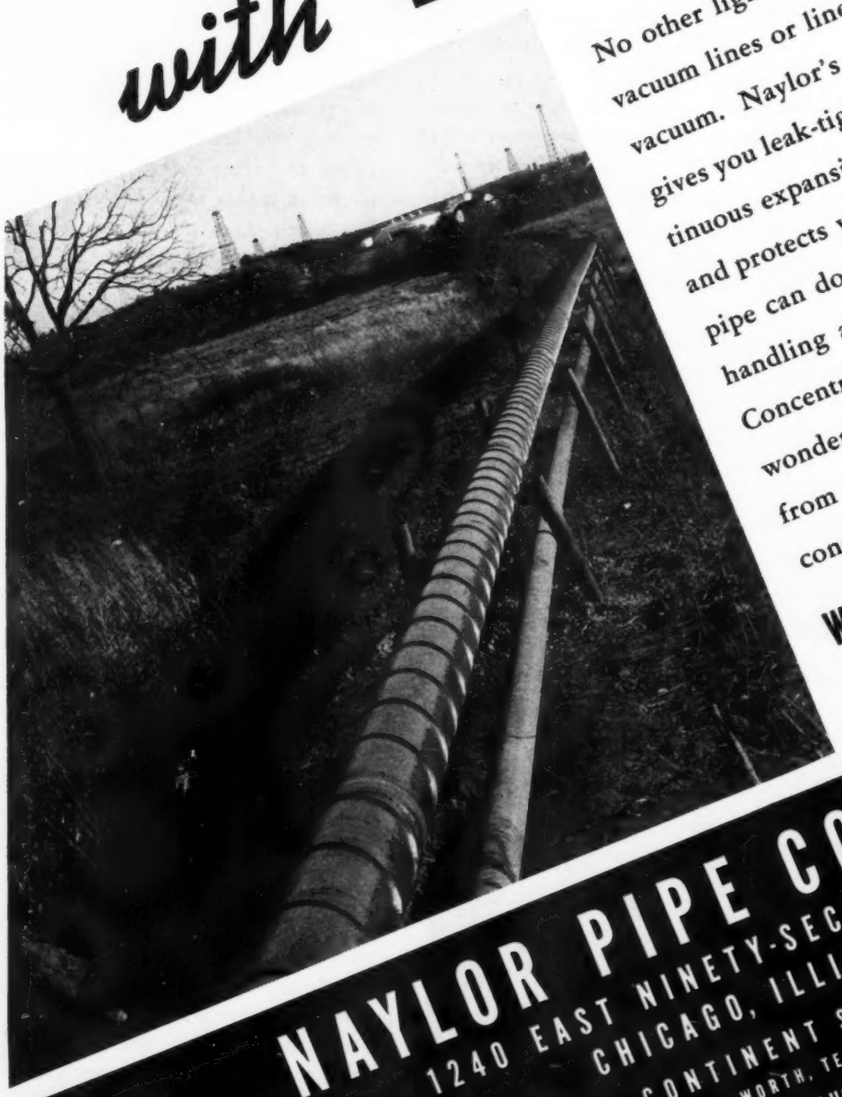

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Installation of Angle-Type Units in Main Line Compressor Station

Flexibility of operation, reduced installation and maintenance costs, and the requirement of less floor space were factors that influenced major pipe line company in making this experimental installation

By GEORGE T. KOCH

Superintendent Compressor Stations, Panhandle Eastern Pipe Line Company

GEORGE T. KOCH

was educated at Columbia University—Upon being mustered out of the army in February, 1919, went to work for The Ohio Fuel Supply Company as a research chemist under Colonel George Bunell—Developed and patented a process for making synthetic amyl acetate from paraffin hydrocarbons—Later was in charge of gasoline plants and compressor stations for the company, operating a group of the Columbia System—Joined staff of Panhandle Eastern in 1936 as assistant in design and construction of compressor stations—Is now superintendent of compressor stations.

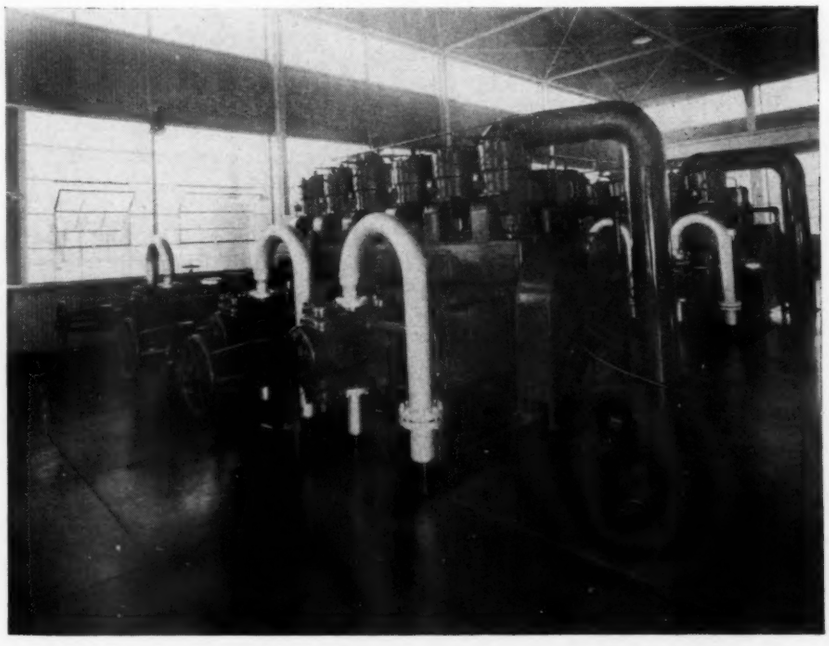
UNTIL a year ago a review of the history of natural gas compression for the purpose of transportation in pipe lines would have revealed that the type of compressor unit first used for this purpose some 40 years ago was still the standard unit, namely, the relatively slow-speed, horizontal, reciprocating type, requiring large floor space, massive concrete foundations, and high buildings with heavy steel superstructures to support traveling cranes for handling the large parts.

With the need for laying larger lines and the extension of existing lines to reach distant markets, and with seasonal load conditions varying widely, gas engineers, designers, and engine builders recognized the need for a small, compact compressor unit that could be economically installed in compressor stations and quickly put into operation to meet peak load demands, providing at the same time flexibility and dependability of operation during overhaul periods and periods of normal and sub-normal operation.

The result of this recognized need and of the study and coöperation of engine builders and gas engineers has been the development of the vertical multi-cylinder gas engine driving direct-connected horizontal compressors. This design, commonly known as the "angle type" offers compactness, accessibility, ease of erection and installation, and many other features, all contributing to lower investment costs per horsepower installed.

The development of this type of unit has been furthered by the advances in the art of metallurgy, which has given to the industry alloy castings, better forgings, heat-resisting steels, and metals of higher tensile strength, which are at the same time more ductile and machineable. Machine tool design, advances in machine shop practices that permit closer tolerance, improvements in speed regulation, gas-mixing devices, ignition systems, packing and piston ring materials, and compressor valve design, are all factors that have contributed to the more rapid development of the high-speed angle-type engines. Both 2-cycle and 4-cycle engines are now available in angle engines, the development of the 2-cycle having been given considerable impetus by the introduction of the pressure fuel-injection system that was first used on horizontal units about ten years ago. This pressure injection system has brought about a 30 to 35 percent economy in fuel compared with the older method of introducing the fuel by mixing with the scavenging air, and has placed 2-cycle engines on a comparable basis with 4-cycle engines with respect to fuel consumption.

(Continued on Page 138)



Two 600-hp. angle-type compressor units installed at Tuscola, Illinois

RECENT GAS PIPEL

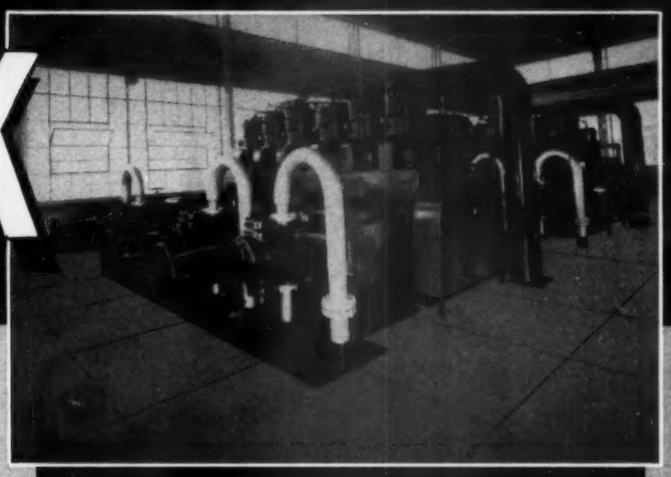
AWARDE

Three 400 H. P. CLARK "Angles", new gas booster station of Consolidated Gas Utilities Corp., Twitty, Texas

Two 600 H. P. CLARK "Angles", new gas booster station of Memphis Natural Gas Company, at Guthrie, La.

LINE CONTRACTS

ED CLARK



Two 600 H. P. CLARK "Angles", new gas booster station of Panhandle Eastern Gas Company, at Tuscola, Ill.

THE CLARK "Angle" is proving the ideal compressor unit for gas booster stations, offering new important economies. A number of leading gas companies, after trying CLARK "Angles" for one installation, have already built their second and third CLARK-Angle-equipped stations.

The installation shown at bottom of opposite page represents one of two "repeat orders" from a leading company. In 1937 the Memphis Natural Gas Company installed five 600 H. P. CLARK "Angles" in its Wilmot, Arkansas, main-line booster station. Early in 1939 this company's new Guthrie, Louisiana, station was equipped with the two 600 H. P. CLARK "Angles" shown. And the company has just completed a third station, at Lulu, Mississippi, equipped with one 600 H. P. CLARK "Angle."

New gas pipe line installations of Consolidated Gas Utilities Corporation and Panhandle Eastern Gas Company are also shown here, while two other new installations not pictured are those of Colorado Interstate Gas Company at Canon City, Colorado, consisting of one 600 H. P. unit, and of the Canadian River Gas Company, at Dalhart, Texas, consisting of four 600 H. P. machines.

CLARK "Angles," while equalling in efficiency and dependability the older horizontal-type compressors, have introduced 4 important economies, viz: Lower transportation and erection costs; smaller foundations and floor space; fuel saving due to CLARK Super-2-Cycle Fuel Injection; lower maintenance due to extreme simplicity of design.

If you will need increased booster facilities in 1940, now is the best time to plan for this expansion. Investigate the facts about CLARK "Angle" savings. Our engineers are at your service.

Basement under Compressor Room, Panhandle Eastern station, showing compressor foundations and pipe connections

Exterior of Compressor Building, Panhandle Eastern Gas Company's Tuscola station

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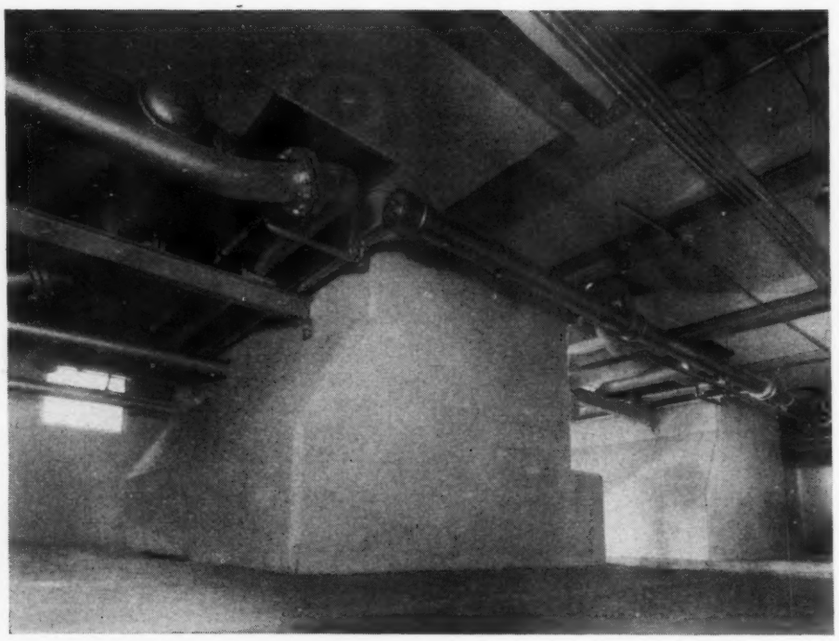
CLARK



Gas headers are situated in basement. The 8-in. pipe passing through sleeve in engine foundation is gas suction line for unit in rear

(*Continued from Page* 135)

During the last three or four years several of the major pipe line companies have installed some of these high-speed angle-type units in their main line stations. In the late summer of 1939 when Panhandle Eastern Pipe Line Company found need for increased horsepower in its Tuscola, Illinois, station serious consideration was given to angle units, with the result that two 600 hp. units were installed and recently have been put into operation. The engines selected and installed were the 2-cycle type having six vertical power cylinders, each cylinder developing 100 hp. at 300 r.p.m. at a brake m.e.p. of 61.3 lb. Power cylinders are equipped with inlet and exhaust ports and fuel is injected at a pressure of 15 lb. through a small poppet valve in the head. Each engine drives three horizontal compressor cylinders arranged at right angles to the power cylinders. Power cylinder and compressor cylinder connecting rods are placed side-by-side on each crankpin. Two double-acting scavenging pumps are used on each engine and are driven through a connecting rod and crosshead from the mainshaft. These two pumps will provide a quantity of air approximately 30 percent in excess of the air required for efficient scavenging of the power cylinders. The power cylinders are 14 in. in diameter and have a 14-in. stroke, which at 300 r.p.m. gives a relatively low piston speed of 700 ft. per min.

The shipping weight of each 600-hp. engine was approximately 82,000 lb. or 164,000 lb. for 1200 hp., as compared with approximately 380,000 lb. for a 1300-hp. horizontal unit. The engines are shipped completely assembled except for the scavenging and compressing cylinders, with the result that erection and assembling time is reduced to a matter of hours.

Maintenance and overhaul will be considerably reduced because of the reduction in weight of the engine parts.

The engines have been arranged in the building so that 1800 hp. can be installed in the area normally alloted to a 1300-hp. horizontal unit.

Each unit drives three 8½-in. diameter, 14-in. stroke compressor cylinders, and at rated speed and 250-lb. gauge intake and 500-lb. gauge suction, has a capacity of 16½ million cu. ft. per 24 hours. Each compressor cylinder is equipped with a variable clearance pocket and one cylinder has a suction valve lifter on the crank end. With this arrangement the unit can be fully loaded at any suction or discharge pressure within the desired operating ranges. The suction valve lifter has the effect of immediately reducing the load 1/6th when opened and capacity can be reduced to one-third of maximum by manipulation of the valve lifter and clearance pockets.

Two exhaust silencers are installed on each engine. Two air cleaners also are used on each engine with a simple deadweight-type of backfire relief valve being installed on each air intake line to prevent damage to the air cleaners in the event of backfire.

As these engines were installed in an existing plant that was operating during the entire installation extra precautionary methods were necessary to eliminate the possibility of explosion or fire. All gas, water, air, and fuel piping was shop-fabricated, with the result that welding on the job was practically eliminated, only three field welds being required to tie the new addition into the old plant. Grade B seamless pipe is used throughout the plant and all joints in gas and air services are slip-flange type. This is also true in water lines with few exceptions. All welds in gas lines and headers are reinforced with welding sleeves and saddles. Headers are equipped with a reinforced bumped welding head on one end and a flanged head on the other end. The purpose of the flanged head is to permit internal inspection in the future if desired.

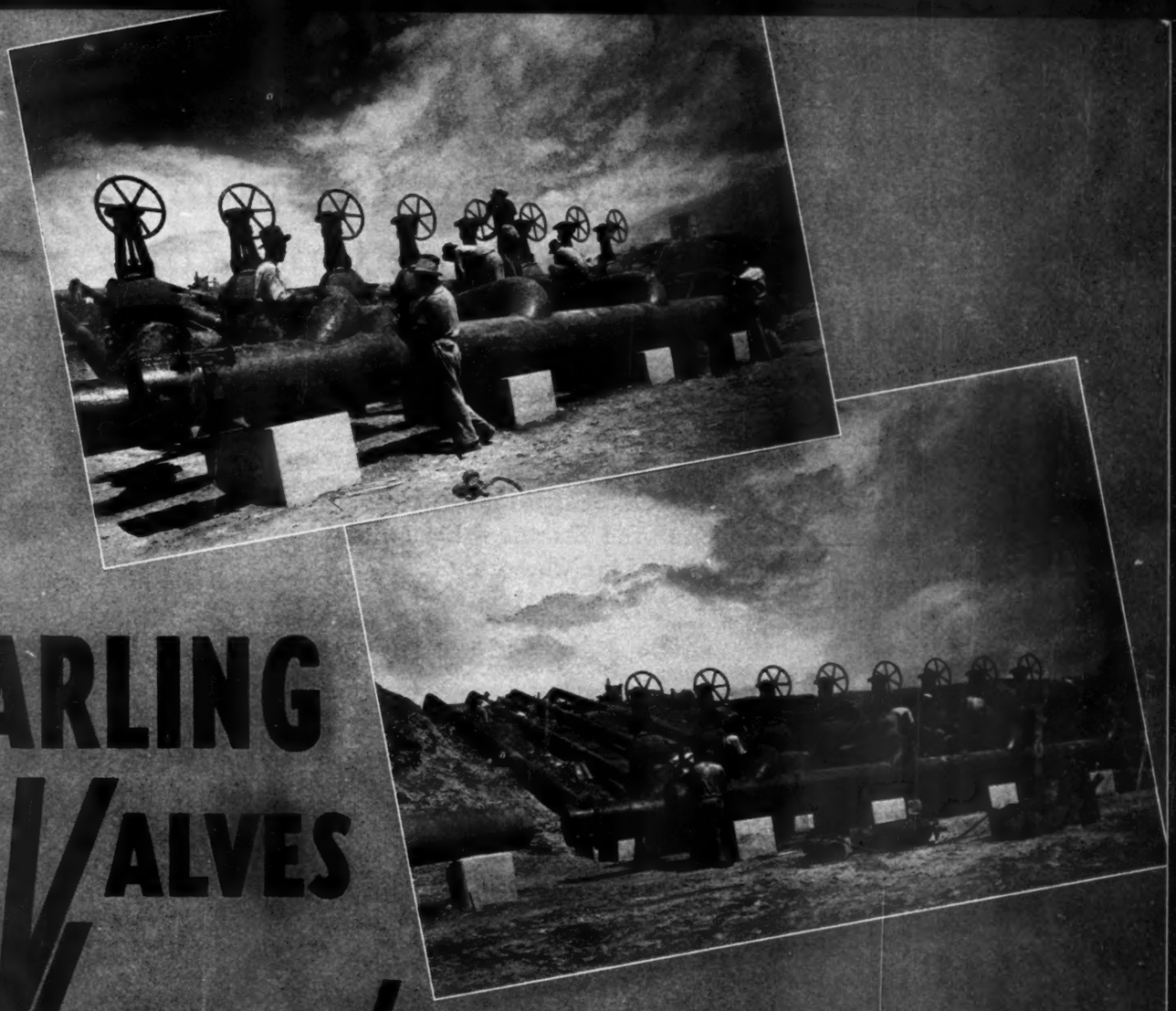
Series 30 flanges are used in all gas piping except at the compressor cylinder intakes and discharges, where Series 60 are used. Flange bolts on all gas-piping valves, compressor cylinders, and on outlet piping at the cooling tower are Class B alloy-steel studs; merchant studs and bolts are used on water, fuel, and air lines.

Cooling-water lines to the engine-jacket exhaust manifolds were designed amply large to permit circulation of large quantities of water to the engines at high velocity when a maximum temperature differential of 20° F. exists between the inlet and outlet.

Assuming 90-100° inlet water, a 20° rise can be maintained by circulating approximately 300 gal. per min. per engine. A 15° rise requires about 425 gal. per min. and a 10° rise slightly more than 600 gal. per min. Water lines as installed are of sufficient size to limit the temperature differential to 15° under any circumstances.

Each engine is provided with an oil cooler in which the circulating oil is cooled after being withdrawn from the crankcase and before being pumped to the upper crankcase for lubrication and cooling of main and connecting-rod bearings and pins.

Frankly, the installation of high-speed angle-type units in a main line compressor station is more or less an experiment as far as Panhandle Eastern is concerned, but all indications are that it will prove to be an interesting and profitable experiment. The high-speed units do not operate as smoothly and as quietly as the larger horizontal units, but little more can be said against them, and these slight disadvantages are undoubtedly offset by the advantages of lower installation cost, smaller floor space, reduced maintenance costs, and flexibility of operation.



DARLING VALVES in Venezuela

The outstanding installation by the Mene Grande Oil Company, illustrated above, is but one example of the increasing use of Darling Valves throughout the world's great oil fields.

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Automatic Devices in Telephone Systems Aid Pipe-Line Operation

Modern equipment includes selector unit that automatically insures communication with only one station on a "party line"—telemetering devices are used for transmitting oil checks from unattended stations

By F. P. O'CONNOR, Superintendent
Telegraph, Telephone, and Electrical Equipment
Stanolind Pipe Line Company

THE last decade has seen the modernization of transportation by rail, air, and automobile, as well as remarkable developments in the transportation of oil and gasoline through pipeline systems, and with this trend the modernization of pipe-line communication systems has kept apace.

The oil-field communication systems of 25 or 30 years ago were almost entirely one-wire systems, but they have gradually developed until the oil companies are now making almost universal use of two-wire copper telephone circuits upon which are used carrier systems, remote control, telemetering, long-line selector systems, and privately-owned intercity PAX systems. Radio is also coming into more general use for emergency communication.

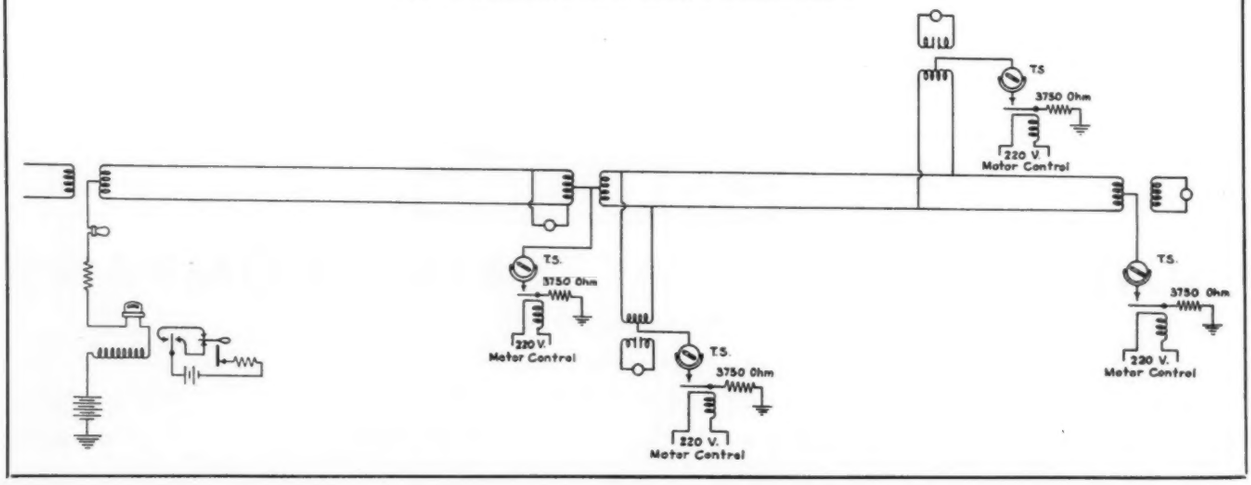
The copper circuits should usually be more carefully transposed for carrier telephone operation than is necessary for ordinary voice frequency service. For best results they should be short spaced to 8 in. or 9¾ in. between conductors of each pair, with approximately 14 in. or more between the various pairs. When carrier circuits are to be used, it is generally unnecessary to retranspose the wires, which are already transposed for voice frequency, except in cases where there is danger of causing interference to some other carrier system on the same pole line. For such conditions it will be necessary to make use of transposition schemes that are especially designed for the purpose.

By use of repeaters or amplifiers these carrier systems are used to operate for distances of more than 500 miles and then can be cross-connected to any other carrier or physical telephone circuit for a similar distance; or "drop channels" can be utilized to drop certain frequencies off the main-line system for side-line operation. These carrier telephones are simply an adaptation of frequencies above the ordinary voice range, which are not high enough to radiate from the wires and become a part of the broadcast band. These frequencies range from 5 kc. to 30 kc.

Remote control and remote signaling devices are rapidly coming into more general usage. Employing such devices, one company is successfully operating gas regulators and pilot lights to indicate differentials in pressure across an orifice, whereas another concern makes use of interrupted d-c. and variable milliammeter readings on the simplexed

F. P. O'CONNOR
has been superintendent of telegraph and telephone and electrical equipment for the Stanolind Pipe Line Company since 1931—Before that he was with the Gulf Pipe Line Company—Was a member of the American Expeditionary Forces during the World War— His headquarters are in Tulsa, Oklahoma.

Fig. 1. Semi-automatic electric station alarm



leg of their telephone circuit to indicate to the oil dispatcher when each of four semi-automatic electric stations start-up and when they shut-down under other than normal conditions.

The operation of this system is shown diagramatically in Fig. 1. These transmitting units operate in connection with a relay in the compensator and a mercury switch on the electric-clock trip mechanism. When the clock operates to the "ON" position both contacts in the circuit are closed until the compensator hits the running position, whereupon the relay becomes energized and breaks its back-contact, thereby opening the circuit. This affords a momentary signal to the dispatcher that the station has started by completing the circuit through a resistor and ground at the station, and a milliammeter and battery at the dispatcher's office. Should any of these stations shut-down from power failure or other cause before the pre-set shutting-down time as shown on his electrical clock, the signal associated with that station will again show on the dispatcher's meter and operate a buzzer to attract his attention. He then calls the field foreman by telephone over the same pair of wires used for this signal system, notifying him which station is in trouble.

At least one pipe line company is making use of telemetering devices to transmit oil checks from the displacement meter at a normally unattended station to one of the main-line stations several miles distant where these impulses are recorded on an electric counter as well as a rate-of-flow chart. This devices is operated over the simplexed leg of a telephone circuit and upon the same circuit with this counter is a howler signal system that operates at a frequency of 120 cycles and is used to summon the day watchman from his cottage at night or during any emergency.

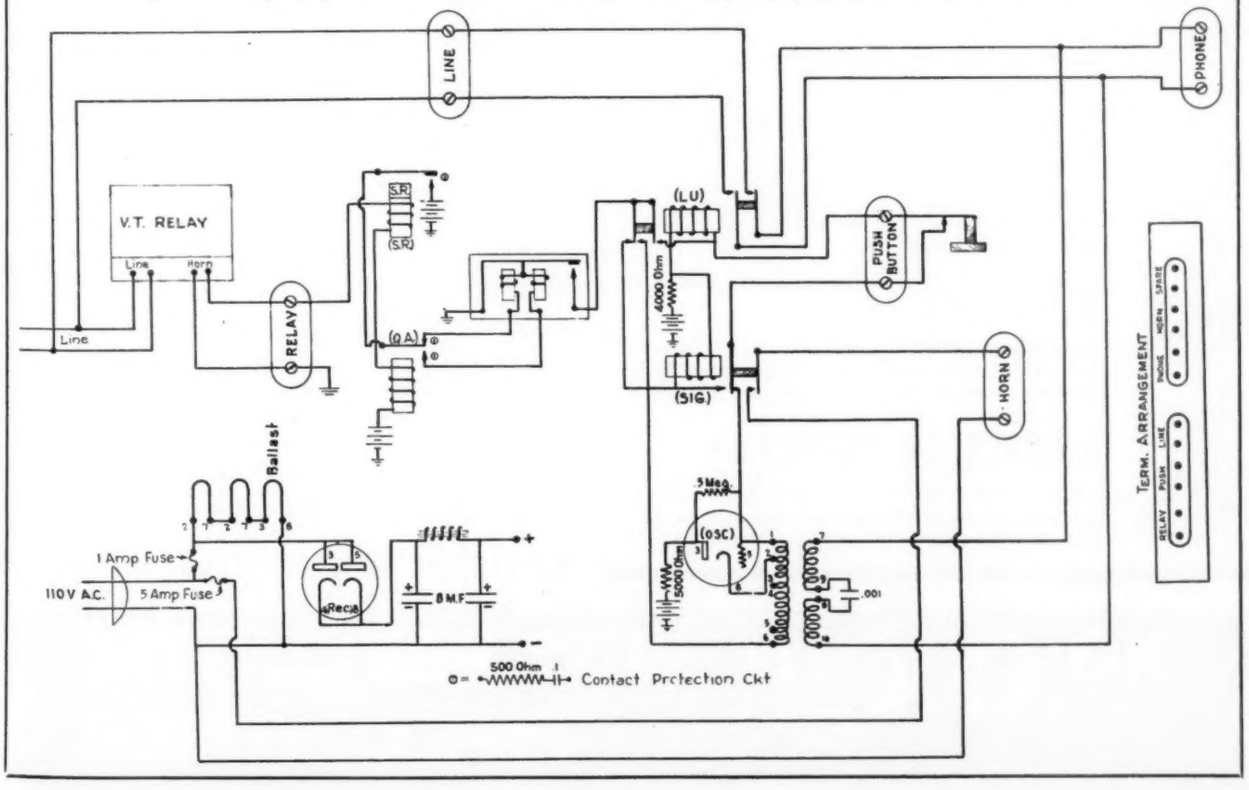
These devices have also been found useful at a number of main-line stations, the charts and meter hour checks being read in the office, whereas it formerly required 20 to 30 minutes of a gauger's time each hour.

A dial selector system has also been developed for use on oil-field telephone systems that eliminates the annoyance of howler operation at every station by operating at only the called station. This system has also proved very useful in connection with stations temporarily shut-down. When installed at the chief engineer's residence, it provides a means for him to call-out at night the workmen at the shut-down station. The system also has proved successful in the case of two line breaks.

Fig. 2 shows a wiring diagram of one of these selector units of the type used for emergency purposes at shut-down stations. The only piece of apparatus permanently connected to the line is the "VT" (vacuum tube) relay, which has been developed to operate on very weak signals and to offer a very low line loss. When dial impulses operate through this relay and cause the selector unit to close in an operated position, the relays LU and SIG are energized. This connects the telephone to the line, energizes the horn, and operates an answer-back signal as notification to the calling station that the signal has operated. When the horn release button is operated, the answer-back signal is also disconnected, permitting the called party to use the circuit. When the conversation is completed, a ring on the line by any station will release the selector. It will be noted that these residence telephones cannot listen-in on the line as they are normally disconnected through the relay, LU, until their station has been selected by one of the control stations.

Another device that has proved rather popular on several pipe-line systems is the transceiver for use by oil dispatchers. The principal use of this instrument is to build-up the received signals to the dispatcher, permitting him to make full and free use of both hands for the handling of his check sheets, and eliminate the necessity of using head phones or desk telephones.

Fig. 2. Wiring diagram of a selector unit used for emergency purposes at shut-down stations



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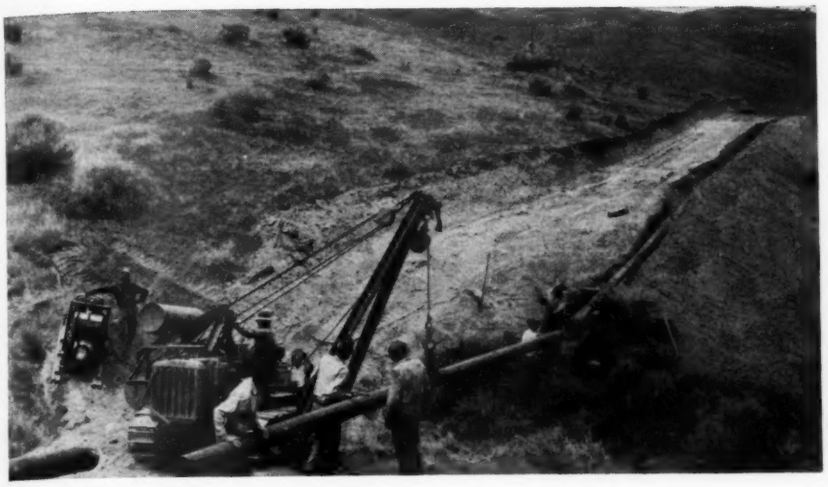


Stove-pipe welding an 8-in. line in Wyoming

A PETROLEUM ENGINEER EXCLUSIVE FEATURE

By
HAROLD C. PRICE
President, H. C. Price Company

Electric-Arc Roll-Welding and Stove-Pipe Welding in Pipe Line Construction

Both methods have their place in construction practice and determination of which to select is dependent upon the kind of line pipe used and the terrain

DURING the last few years there has been considerable argument among pipe-line contractors regarding the feasibility of using the stove-pipe method of welding on pipe-line construction. Some favor it, some do not, all basing their judgment on actual past experience under different condition. The experiences of this company's welding crews throughout the country at all seasons of the year, bring us to the decision that there are conditions under which stove-piping is preferable, whereas under other circumstances roll-welding should be employed.

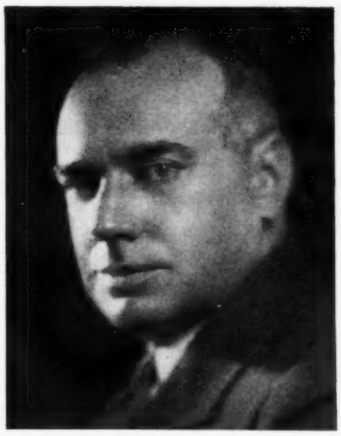
First, it is necessary that the construction details of each method be briefly reviewed.

Roll-Welding

In roll-welding the pipe is lined-up and tack-welded on dollies and skids by a line-up crew using a boom tractor, and then roll-welded into sections averaging 200 ft. in length. This is performed ahead of the ditching machine. After the long lengths are welded, the sections must be lifted off the dollies and placed on the right-of-way. After the ditch is dug the pipe gang swings these long lengths over the ditch where they are welded into a solid line by the tie-in welders.

Stove-Pipe Method

When stove-piping, each joint of pipe is placed on skids across the ditch, tacked in position, and welded into the completed line. All welds are position welds. Bends are either made on single joints ahead of the pipe gang or made immediately following the welding of each joint.



HAROLD C. PRICE

graduated from the Colorado School of Mines in 1913—Was with the American Metals Company as chemist and metallurgist from 1914 to 1921, except for the period of the World War—Became an electric-welding contractor in 1921—Is president of the H. C. Price Company, electric-welding contractors of Bartlesville, Oklahoma.

The most evident advantage of stove-pipe welding is the saving in cost. This saving results from:

1. Elimination of line-up gang.
2. Moving pipe only once, when it is placed over the ditch.
3. Use of smaller equipment, both for welding and handling pipe.
4. Less right-of-way and property damage.

The great disadvantage of the stove-pipe method is the limitation to daily progress. This is definitely limited by the speed with which the ditch is made, as no pipe can be welded until the ditch is ready, whereas in sectional or roll-welding, if the ditching is delayed, the firing-line or main welding crew is not shut-down, and at least that much progress can be maintained daily. Also, it is evident that if there is much bending to be done the lining-up and bending over the ditch will be slower than lining-up and bending in long straight sections ahead of the ditch.

Position welding is slower than roll-welding, therefore it will take more welders to make the same footage per day. It usually takes one or two additional welders per gang. All the welders must be able to make position welds.

The above gives the general advantages and disadvantages of the two methods. Other factors, particularly the size and thickness of pipe, the terrain, and the weather, must be taken into consideration.

Factors favorable to stove-pipe welding are:

(a) Use of small-diameter pipe.
(b) Use of light-weight pipe.
(c) Very rough country.

Roll-welding an 8-in. oil line

(d) Muddy or swampy country.

Factors favorable to roll-welding are:

(a) Use of pipe not more than 12-in. diameter.

(b) Use of heavy pipe.

(c) Level country with no obstructions.

(d) Country where it is difficult to dig ditch, such as rock or frozen ground.

Size of Pipe

Small-diameter, light-weight pipe can be welded almost as fast by the stove-pipe as by the rolling method. Small-diameter welding rods are used in both cases. Light-weight pipe requires three beads, both for roll welds and position welds. Pipe of more than $\frac{5}{16}$-in. thickness requires at least four beads for position welds but only three beads for roll-welds. Pipe of 6-in. or less diameter should always be stove-piped unless there is difficulty with the ditching. In most cases this also applies to 8-in. pipe. The method used for 10-in. and 12-in. pipe depends on other conditions.

Terrain and Weather Conditions

In extremely rough and mountainous country, construction progress is slowed up because of difficulty in transporting equipment along the right-of-way. In Pennsylvania and West Virginia, for example, one-half mile per day is usually the average welding progress, regardless of the size of pipe, even when roll-welding is used. The same progress can be made by stove-piping with less cost, even on large-diameter pipe.

In level country the opposite situation exists, particularly if there are no detours. A firing-line can roll-weld a minimum of 2 miles and sometimes 3 and 4 miles per day, and the pipe gang can lay the same amount. A stove-pipe gang would not average more than two miles per day. Therefore, on 8-, 10-, and 12-in. pipe the writer would recommend roll-welding in this kind of terrain.

In muddy or swampy country the same difficulty is encountered as in rough country, as the maller the amount of heavy equipment used the better the progress made. Therefore, stove-piping should be used on all sizes of pipe including 12-in.

In very cold weather, where the ground is likely to be frozen, roll-welding should be employed. The frozen ground will not delay the moving of the line-up and the firing-line machines, therefore that much work can be performed even if cutting of the ditch is held-up. This applies for pipe of all sizes, even 6-in. or smaller.

Continuous wind is a handicap to stove-pipe welding, particularly if the ditch is parallel to the prevailing winds. The air currents will go down into and along the ditch. This will cause the welding crews to be shut-down more often than if they were roll-welding away from the ditch with higher electric currents and larger rod.

Summary

It is evident from the foregoing that it is erroneous to state that one method of welding is preferable to the other under all conditions. By the development of stove-pipe welding the technique has been improved and the cost of laying pipe lines reduced, but only when that method is applicable.

Lining-up an 18-in. gas line for welding

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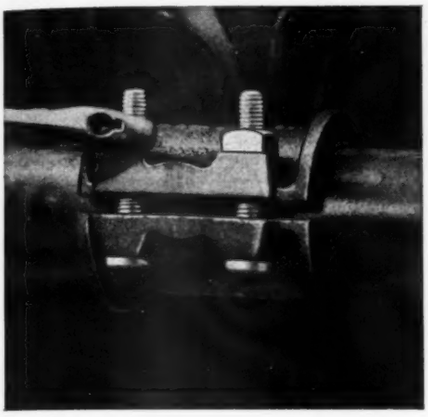

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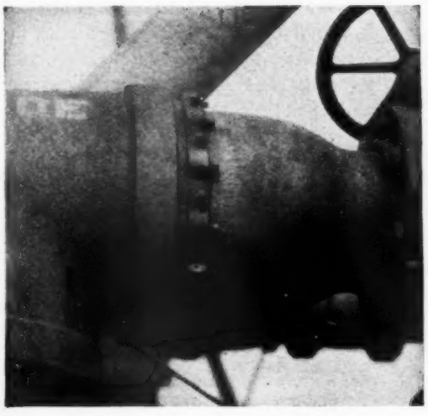

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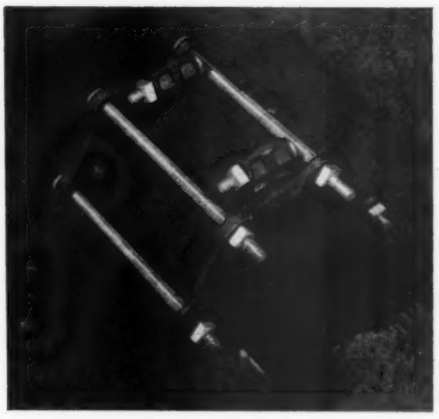

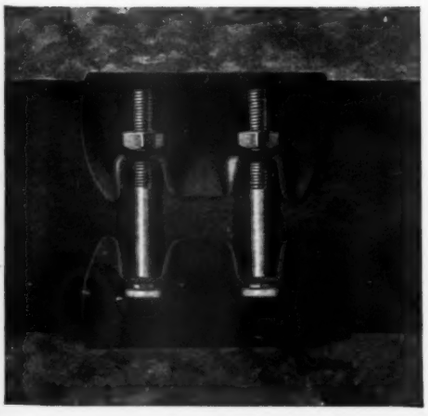

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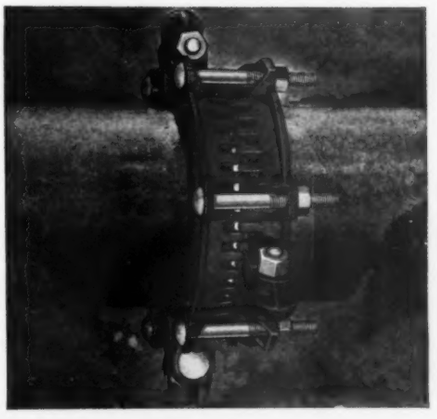

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Hydrate Control in High-Pressure Condensate Lines

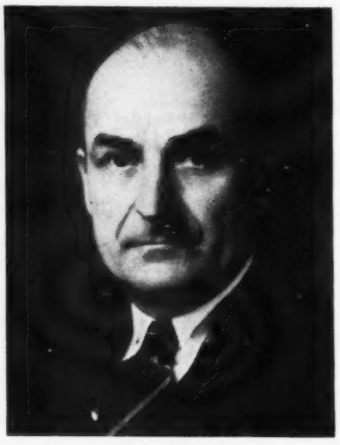
A PETROLEUM ENGINEER EXCLUSIVE FEATURE

Stage pressure reduction and condensate removal combined with application of controlled heat and insulation represent probably most economic and efficient method

By ROBERT M. HUTCHISON
Chief Engineer, Houston Natural Gas Company

ONE of the worst headaches experienced by the gas engineer of today is the handling of gas from so-called high-pressure distillate wells. Perhaps condensate is a better name because condensation causes most of the trouble. Each time pressure is reduced, certain gas constituents change from the vapor to the liquid phase and if water is present and the temperature low enough, gas hydrates will form either at a regulator or in the pipe line. Water is usually present and, therefore, hydrate formation generally can be expected. This occurs when the temperature or pressure is favorable.

Temperature fluctuations may be caused by atmospheric changes or by a variation in the rate of gas flow; thus it follows that control of either of these conditions will have a tendency to retard hydrate formation. Research and experiments in the application of the theory of retrograde condensation and vaporization have proved the value of stage separation in the removal of liquids from natural gas. Assistance in avoiding hydrates can, therefore, also be obtained by stage reduction of pressure accompanied by the removal of condensate as each pressure reduction is effected.

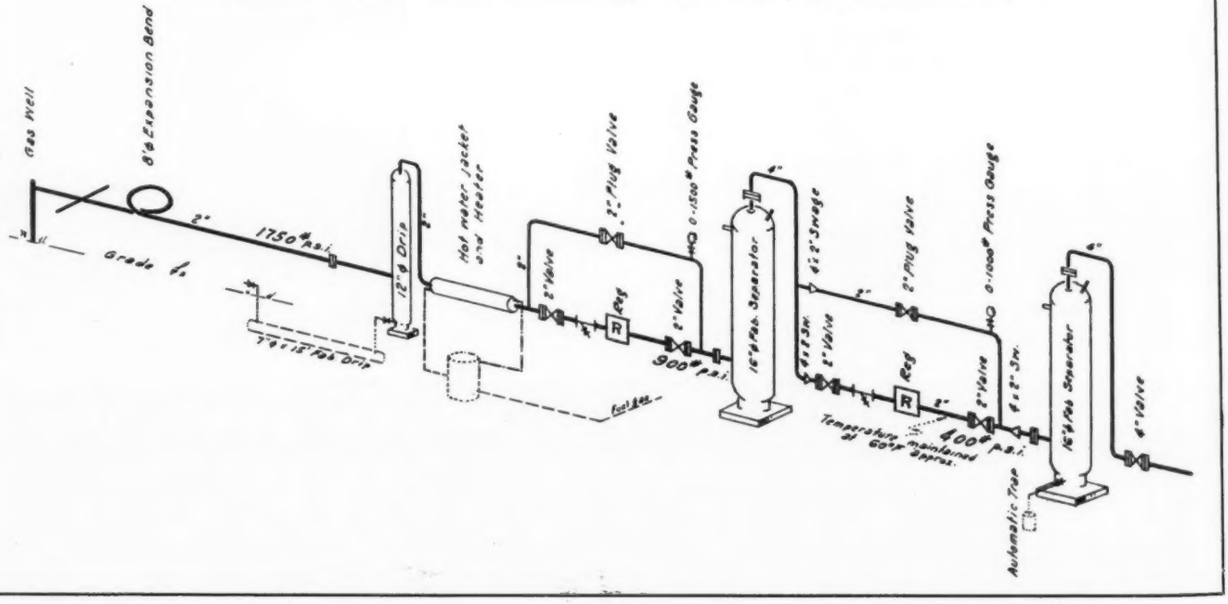


ROBERT M. HUTCHISON

is an alumnus of Pennsylvania State College—Has been affiliated with the Houston Natural Gas Company for the last ten years—Is the developer of the Hutchison Rapid Calculator for pipe-line flow and of the H. & H. By-Pass Type Odorizer.

Gas temperatures at the wellhead may vary from 60° to 120°F. or possibly higher and, in many cases, some hydrocarbon fractions can be recovered at this point. It will be advantageous therefore to install a suitable separator or drip as near the wellhead as practicable. An installation of this type will remove such liquids as will condense under existing conditions of temperature and pressure, and thus the possibility of hydrate formation during subsequent pressure reductions will be lessened. This is especially true if the gas temperature at the wellhead can be maintained, which can be accomplished by insulating all equipment aboveground. The value of this practice lies in the protection against the influence of atmospheric temperature changes that, as stated, play an important part in this problem. There are several ways of preventing hydrate formation, viz: dehydration; refrigera-

Sketch showing installation used to control hydrates in high-pressure condensate lines



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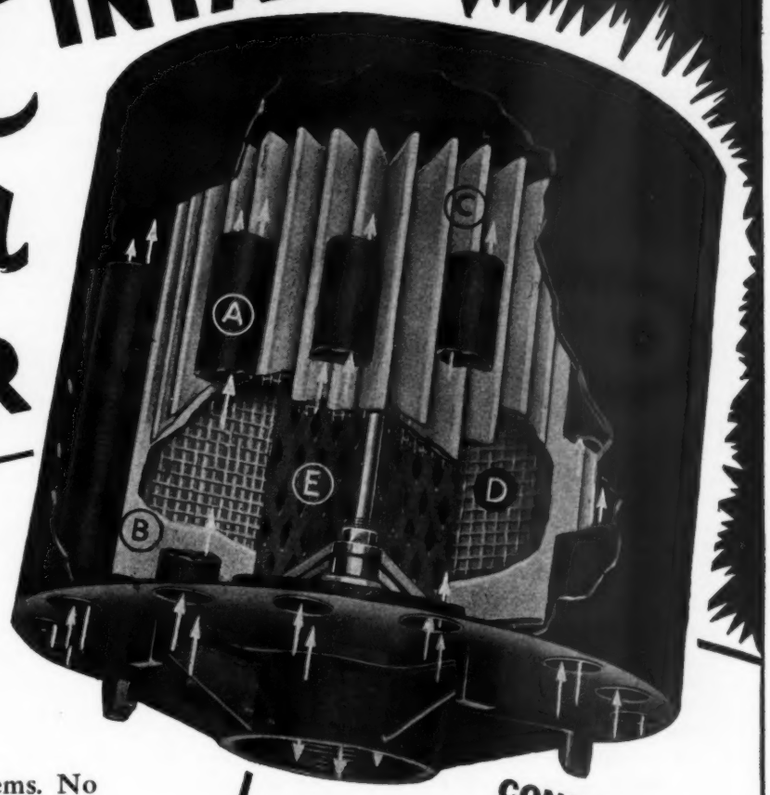

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tion; the introduction of inhibitors such as calcium chloride, alcohol, ammonia, or some other chemical into the gas stream, and heat.

Dehydration and refrigeration are usually quite expensive and the injection of inhibitors is not always desirable, so in the majority of cases the operator has resorted to the use of heat. Nor have his efforts been in vain even in cases where the heaters were crude affairs and no attempt was made to control temperatures. Experience, however, has proved the value of heat control in connection with this problem and the intent of this article is to show why.

In recycling plants it is the aim of the operator to recover as much liquid as possible before returning the gas to the reservoir. In short, he wants to strip the gas of all liquid hydrocarbons if possible. This is true whether he uses stage separation, absorption, or both, and both processes depend largely on temperature control for efficiency of operation. The distributor of natural gas likewise is desirous of obtaining dry gas for more reasons than one, so it would appear logical for him to use the most economically efficient methods when designing regulator stations to be used on high-pressure distillate wells. These seem to be stage reduction of pressure combined with heat control and insulation.

The number of stages of pressure reduction to be employed can easily be determined and there are several types of regulators that will give satisfactory results. The most satisfactory service will probably be obtained, however, from regulators having the least turbulent effect on the gas at the point of pressure reduction. A suitable separator or drip should be installed at the well, as stated, and also after each pressure reduction. The necessity for this is obvious. Stage reduction is accompanied by successive condensation of the heavier hydrocarbons in the gas. The drips will remove the condensate that forms according to the existing temperature and pressure at each reduction.

The next consideration is the application of heat, because a temperature rarely if ever exists at the wellhead sufficient to guarantee freedom from hydrates under all conditions. During warm weather such temperatures may exist for part of the day, but rain, clouds, or darkness may cause enough change in atmospheric conditions to cause regulator or line freezing. Thermostatically controlled heat, therefore, seems to be the answer.

There are no doubt many types of heaters in use that could be depended upon, but for this kind of service one in which water is used as the heating medium likely will prove most satisfactory. The gas passing through a pipe coil enclosed in the water bath is heated to the desired temperature by hot water. Either a closed- or open-type heater may be used to the same advantage. The gas should pass through the coil so that the hottest gas will come in contact with the hottest water. The heater should be installed somewhere between the drip at the well and the first regulator (never ahead of this drip) because the hotter the gas at this point, the less will be the liquid recovery.

To determine experimentally what temperatures should be maintained, thermometers should be installed in the gas stream and the hydrate formation temperature determined by allowing hydrates to form. The thermostat on the heater can then be set so that the temperature of the gas after it passes the last regulator will be above that at which hydrates form. An installation such as this will operate satisfactorily in most weather conditions experienced in the Gulf Coast area, but if all drips, regulators, lines, and fittings be insulated with rock, cork, or wool, and waterproofed, final gas temperatures can be closely controlled. Charts from recording thermometers installed on an assembly of this kind show a variation of only 4 deg. regardless of weather conditions.

Such a regulator station requires very little attention and enables the operating man to go to bed on cold nights with a clear conscience.

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HIGHLY-IMPORTANT information about the serviceability of various types of protective coatings for petroleum and natural-gas pipe lines will be gathered in the spring and summer of 1940 when final inspections are made of hundreds of test coatings that have been in service in all parts of the country on sections of working pipe lines and other pipes for a period of 10 years.

The sample coatings were installed in 1930 as a coöperative undertaking of the American Petroleum Institute, the National Bureau of Standards, and the manufacturers of protective coatings, in an attempt to determine the value of different types of coatings under varying soil and operating conditions.

The final tests, which will be made under the supervision of the Bureau of Standards, include: soil resistivity measurements, current on working lines, pattern tests for location of pinholes, coating resistance, inspection of coatings, and measurements of pit depths. It is expected that photographs of each coating will be taken.

Tests are scheduled to begin in March, continuing with few interruptions until August. The schedule is so arranged that the same inspectors may view all tests, giving greater comparability and completeness than otherwise would be possible. The first report will be presented at the American Petroleum Institute's 21st Annual Meeting at Chicago in November.

Because of the unusual opportunity to collect important first-hand evidence, however, the Institute's Topical Committee on Pipe-Line Technology has decided to permit any interested individual or company representative to be present when the test coatings are exposed. K. H. Logan, chief, Underground Corrosion Section, National Bureau of Standards, Washington, D. C., will provide schedules of test locations, coatings, and dates, and make arrangements to keep anyone wishing it informed of changes in the schedule.

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P 615.61
P 405.3

Modern Equipment is Adopted in Pipe Line Communications

Radio and teletype are becoming standard items —magnetic telephone is new instrument used to advantage in certain applications

By WARREN T. BULLA

Superintendent, Telephone and Gas Dispatching, Natural Gas Pipeline Company of America

RAPID, dependable communication is of vital importance to all oil, gas and pipe-line companies. The very nature of the business requires that much of the work carried on be expedited as much as possible and there is a necessity for good communication for any industry conducting operations over the vast amount of territory encompassed by the average oil or gas company. Particularly is this true in the companies owning "long-haul" pipe lines transporting oil, gas, or gasoline through hundreds of miles of line. These operating companies require communication services as extensive as those used by railroads in order that key points may be regulated to move the proper quantity of the transported commodity from the field to the market in accordance with consumer requirements. The control problem has always been a matter of concern in operating long transmission lines. With the availability of improved mechanical equipment, however, and by the application of a reasonable amount of communication facilities, the pipe-line systems of today have been able to develop special departments, the functions of which are coördinated into a smooth routine that has improved their service materially.

The varied and indispensable uses for which oil, gas and gasoline are being employed make service continuity an absolute necessity. Otherwise, consumers (home owners, electric generating plants, hospitals, glass plants, cement plants, foundries, smelters, and other industries), sustain huge losses, which in the aggregate may reach proportions many times the revenue loss in terms of cubic feet of gas or gallons of oil.

Pipe lines usually are constructed over a route that is the shortest distance between terminals, assuming that problems of topography, right-of-way, etc., are equal with respect to all proposed routes. Little consideration is given to questions of proximity to highways, towns, and commercial telephones and telegraph service. Thus, the pipe lines are generally forced to provide their own means of communication in some form.

WARREN T. BULLA

was connected with the Southwestern Bell Telephone Company for five years prior to becoming affiliated with the oil and gas industry—For 12 years was variously wire chief, assistant superintendent, and superintendent of the communication system of the Empire Companies—From June, 1930, to July, 1931, was employed by the Continental Construction Corporation to plan and construct the communication system for the Natural Gas Pipeline Company of America, which extends from Texas to Chicago—Has since been in charge of communications and gas dispatching for the company.

Communication is a progressive and fast-moving art. It is probable that all known types of communication have been used at one time or another in serving the petroleum industry, including such primitive devices as smoke signals and flags. The more common devices employed, however, are the electrical methods; these include telephone, telegraph, and radio.

Telephone and telegraph types of service are used principally, although teletype is rapidly displacing telegraph and some companies are now using radio.

Most of the large companies have a communication department charged with the responsibility of providing adequate service. This is done by obtaining service through one of the commercial telephone and telegraph companies or by erecting company-owned lines; the usual practice is to plan a combination of both. Controlling the maintenance of good facilities, usually from a centrally-situated point, is the wire chief's office. In Fig. 1 are shown the principal "tools" required by a wire chief. In his everyday work a wire chief makes use of the elements of electricity in a practical way to maintain the communication plant so it will give good service. His tests and locations determine largely the speed with which trouble is cleared.

The principal items shown in Fig. 1 are: a group of terminating jacks on a test panel unit, including a voltmeter and a wheatstone bridge circuit, which provide facilities for detecting practically all kinds of telephone and telegraph line trouble. Telephone repeaters are included as well as telegraph sets and a position-type telephone switchboard.

In communication by telegraph or radio-telegraphy, a code is used consisting of "dots" and "dashes"; this requires an operator capable of sending and receiving in code, whereas by telephone or radio-telephony the voice itself is transmitted and no code is necessary. For this reason most companies have favored telephone service as the more desirable.

Pole lines are necessary if the wires are to be strung; 20-ft. and 25-ft. length poles are most commonly used, placed either along pipe-line routes or along adjacent highways; or, where pole lines of other companies exist, pin space can usually be obtained on a rental basis.

A minor item, but important nevertheless in reducing maintenance costs, is the new rubber line-wire insulator

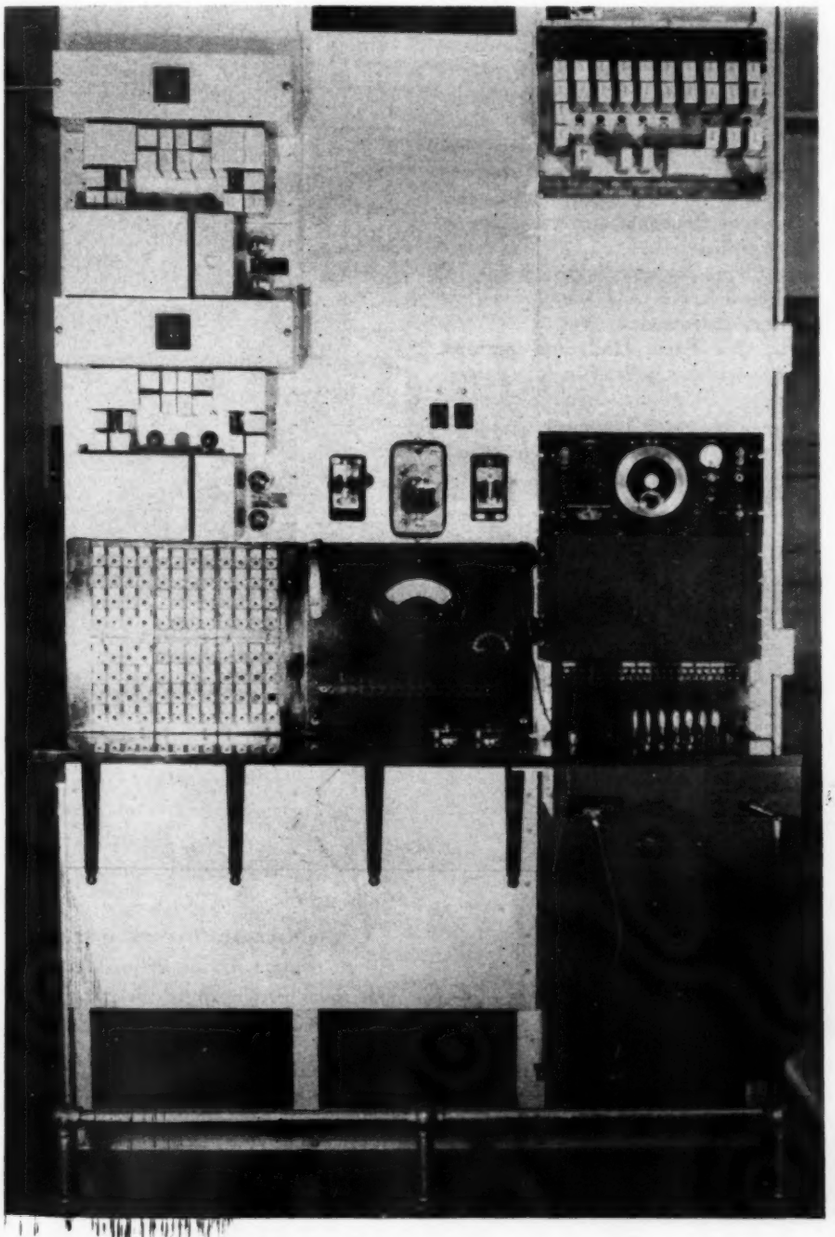
developed for use where frequent breakage of glass insulators has been experienced. Operating data on use of this piece of equipment should be available at a later date.

In the early days, iron wire was erected for telegraph circuits, but was not found so satisfactory for telephony because of energy losses in the wires. Hard-drawn copper wire is quite generally used as it is mechanically strong and electrically efficient.

For years it has been common practice in arranging circuits to erect two wires for telephone use primarily but to use them also for telegraph service by superposing telegraph on telephone circuits. Another adaptation, where two telephone circuits parallel each other, has been to create a third (phantom) circuit by bridging balanced transformers across the ends of the two parallel physical circuits. Using modern methods, a good two-wire copper circuit can provide eight telephone or talking channels and telegraph or printer channels.

Telephones and switchboards generally used on oil, gas, and pipe-line private communication systems are of the magneto type, which is quite satisfactory for this service.

Fig. 1. Telephone and telegraph testing equipment used by a major pipe line company



The use of telephone repeaters (amplifiers) provides for satisfactory transmission over long circuits. Many of the circuits constructed for use in these private systems were not originally intended for "long-haul" use, but as the company's operations expand, the telephone circuits are extended and these repeaters permit a satisfactory voice level to be maintained.

Intercommunication service in large plants such as refineries and terminal bulk plants, etc., is conducted very efficiently on a system without an operator. These can be purchased outright, or, in many localities, obtained on a rental basis.

A relatively new piece of equipment is the "magnetic telephone," a sound-powered unit that functions both in the transmission and reception of speech and signals without the use of batteries or other external source of power or excitation. It is intended primarily for service in such places as ships, refineries, gasoline plants, in fact, any place where dependable facilities would be advantageous.

The magnetic telephone is mounted on die cast metal and is protected from injury and weather by a semi-hard rubber housing. The set has a two-conductor waterproof cord with clips for connection to the telephone circuit. The unit is rugged and light in weight, weighing approximately 2 lb. It is a highly efficient receiver structure of the balanced-armature type. In the transmission of speech, the sound waves vibrate the diaphragm, which in turn moves an armature back and forth in the field of the permanent magnet, thus causing variations of the magnetic field through the armature. When this alternating potential is impressed on a second or called telephone, the magnetic field of that instrument is varied through the armature and the armature vibrates the diaphragm to reproduce speech.

Teletype or printer equipment is gradually replacing telegraph operators, and is found very serviceable. Many improvements have made this equipment nearly fool-proof. It can be had in several styles to print on tape or page, or perforate a tape so messages can be re-sent at relay offices. A typical full-duplex teletype set-up in use in a gasoline pump station is shown in Fig. 2. Two complete teletype units are used. Duplex operation provides for the simultaneous transmission and reception at such a station. When the operator at the general office signals a field teletype station, an automatic signal-back is received (if the line is not in trouble), and then the motor of the distant teletype machine is automatically started, obviating the need for

the distant operator to in any way supervise an incoming message.

Radio service is a new facility that will probably assume an important place in the oil, gas, and pipe-line companies' emergency equipment.

It enables operating companies to dispatch their repair crews to the scene of an emergency in a matter of a few minutes.

Advantages of special emergency radio service in pipe-line work are:

(1) Better protection of property
(2) Continuity of service to consumers
(3) Instant communication to maintenance crews
(4) Better utilization and supervision of men and equipment during emergencies.

Radio has been successfully used as an only means of communication in connection with the "wildcat" drilling operations in progress in the far northwest on the Alaskan peninsula; also the farthest north refinery situated at Norman Wells, Canada, maintains communication by radio through the Royal Canadian Signal Corps Station at Fort Norman.

Some oil companies are using radio to provide communication between tankers and barges operating in the Gulf Coast swamp area, and many tankers are using radio for contact between boats on ship-to-ship and ship-to-shore service.

Several oil, gas, and pipe-line companies have been authorized to operate special emergency radio stations. One of such assignments is that of the Natural Gas Pipeline Company of America, which is operating six transmitters on a medium high frequency, transmitting emergency communications to maintenance cars and trucks. A field station set-up for operation is shown in Fig. 3. Included in the equipment is a 50-watt radiotelephone transmitter and receiver, crystal-controlled for simple operation on a single frequency. A typical telephone handset is used as a microphone, which with the use of a long cord will provide communication to a remote location such as to a pipeline ditch. The field desk and stool are converted into carrying cases when in transit. Other principal items necessary but not shown in this picture are the antenna, power supply, and umbrella tent.

The Federal Communications Commission has indicated by recent authorizations that it is appreciative of the valuable service to the public to be derived from radio used in special emergency service by public utilities. The commission in its "Rules Governing Emergency Radio Services," allocates a number of frequencies to special emergency stations:

(a) For portable stations with a maximum power of 1 watt: Seven ultra-high frequencies.

(b) For fixed, land, and portable stations without limitation as to power: Three ultra-high frequencies.

(c) For fixed, land, and portable stations with a maximum power of 1000 watts: Two medium high frequencies, one for telephony and one for telegraphy.

(d) For fixed, land, and portable stations of public utilities using telephony with a maximum power of 50 watts: Two medium high frequencies, one restricted to day-use only, and both subject to the condition that no interference is caused to other services.

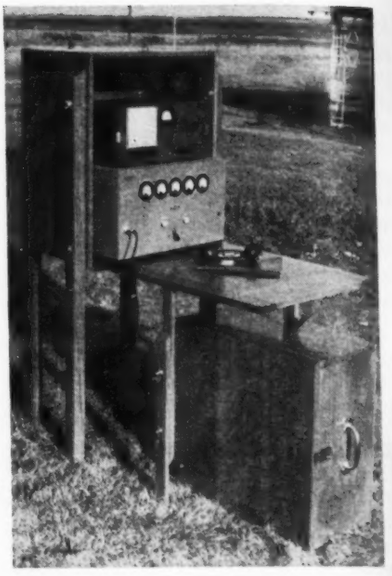
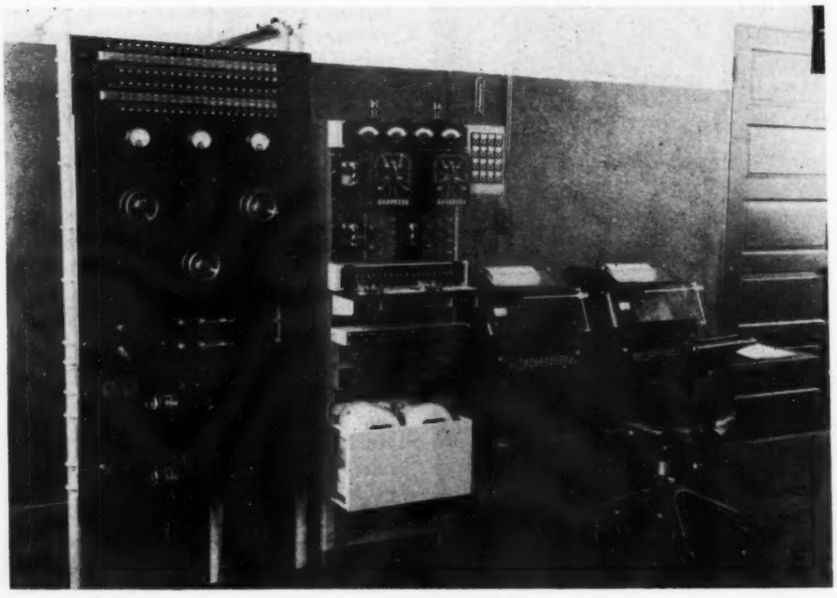


Fig. 3. Emergency radio equipment as set-up for use in the field

Fig. 2. A typical full-duplex teletype set-up (shown to the right of the control board) in use in a gasoline pumping station



Some experimental work has been done to develop a communication system designed for employing long-distance metallic objects, such as pipe lines, railway rails, etc., as guides for electromagnetic waves, whereby nonreturn electrical circuits may be established for rendering low-energy services, such as telephone and telegraph communications, and other services requiring very little energy.

The outcome depends on a number of factors, including favorable recognition by the Federal Communications Commission.

One oil company has set-up a talking circuit using a section of pipe line several miles in length as the conductor, and although few data are available as to their experience, it is imagined that there are problems, particularly in maintaining a satisfactory grade of transmission. It is doubted if such an arrangement could be made to operate over as much as 50 miles of line.

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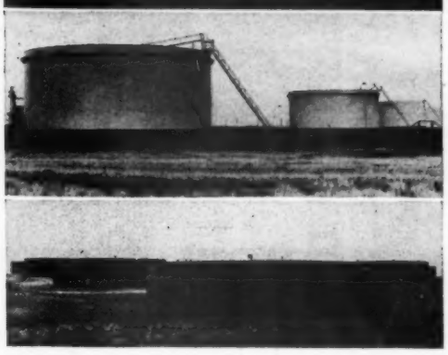

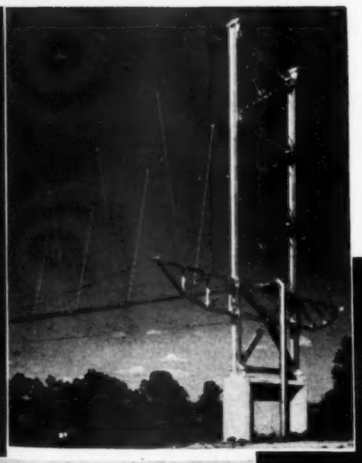

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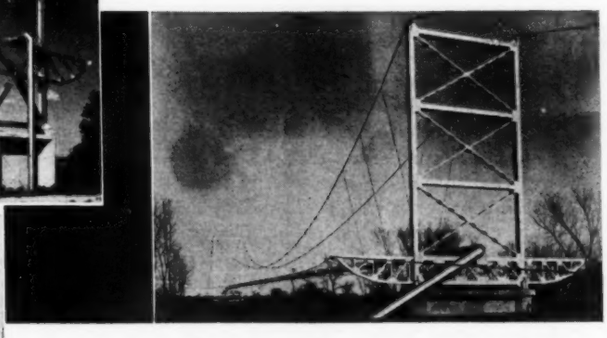

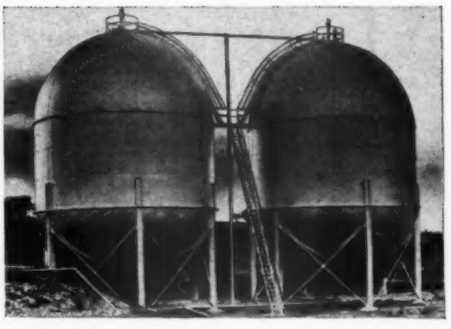

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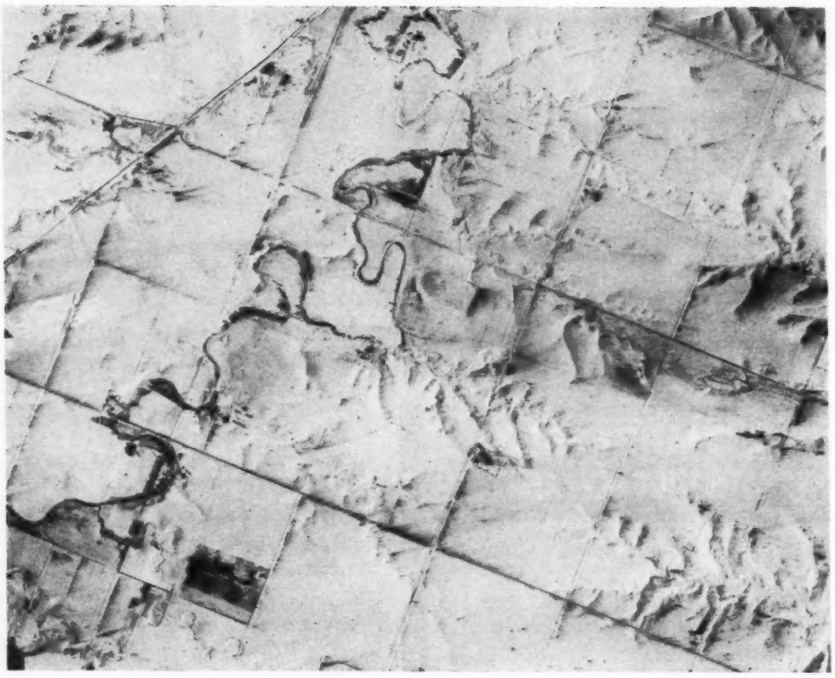

Aerial photograph of snow-covered terrain taken from an altitude of approximately three miles

A PETROLEUM ENGINEER EXCLUSIVE FEATURE

By
FRANK H. LOVE
Managing Editor

Snow-Covered Pipe-Line Right-of-Way Photographed From Air

Results refute popular opinion that advises against the taking of pictures to show surface conditions when any element is present that might obscure visibility

RESULTS obtained in photographing from the air a pipe-line right-of-way covered by 12 to 15 inches of snow definitely refute the popular opinion that advises against the taking of pictures to show surface conditions when any element is present that apparently obscures visibility. This work was done on January 20 by the Aero Exploration Company of Tulsa, Oklahoma, for the Stanolind Pipe Line Company, in making the location for that company's proposed line from the Bemis pool, Ellis County, Kansas, to a point near Washington, Kansas, where it will tie-into the trunk system from Wyoming.

An example of the photographs taken, reproduced with this article, is illustrative of the success with which property tracts, roads, culture, drainage, topography, etc., have been delineated in these planimetric maps. This illustration was selected because it presents a variety of conditions. The photograph was taken from an altitude of approximately 15,000 ft. and the clear relief of surface conditions is readily discernable. In fact, it would seem that in certain instances the snow covering has enhanced the topographic study rather than impaired it. For example, the banks of the stream that winds upward from near the lower left-hand corner of the illustration to the top center portion appear dark, due to the shadows cast by the leafless trees on the snow below. The length of the shadow indicates the height of tree. These shadows are more evident on the snow-covered ground. The trees, being leafless, allow a closer observation of the river banks. In other instances, perception also does not seem to have been impaired. It is interesting to note the railroad that traverses diagonally across the upper left-hand corner of the illustration, the numerous roads, fences, gulleys and cultivated and uncultivated fields. Certain areas on the map are seen to be almost devoid of snow. These generally are wheat fields where the smooth surface has allowed the snow to be blown off. Other fields covered with grass, wheat stubble, or corn stalks retained the snow and appear white. An interesting observation in connection with the gulleys is the illusion of reverse relief. Those who have studied aerial photographs are familiar with the optical illusion resulting from highlights and shadows that causes the photograph to appear in reverse. The gulleys in the accompanying illustration, when observed from certain angles, appear to be ridges. This illusion of reverse relief, indicative of extremely sharp detail, is more apparent on snow photographs, which has led those connected with the survey, the first ever to be made of a pipe-line right-of-way completely covered by snow, to consider it another indication that topographic studies are not impaired but enhanced by the presence of snow.

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Selection of Electric Motors for Pipe-Line Service and Cost of Maintaining Them

Study of past installations indicates 3600-r.p.m. induction motors are favored—maintenance costs are found to vary from 1 cent to 40 cents per hp. per year

By W. H. STUEVE
Oklahoma Gas and Electric Company,
Oklahoma City, Oklahoma

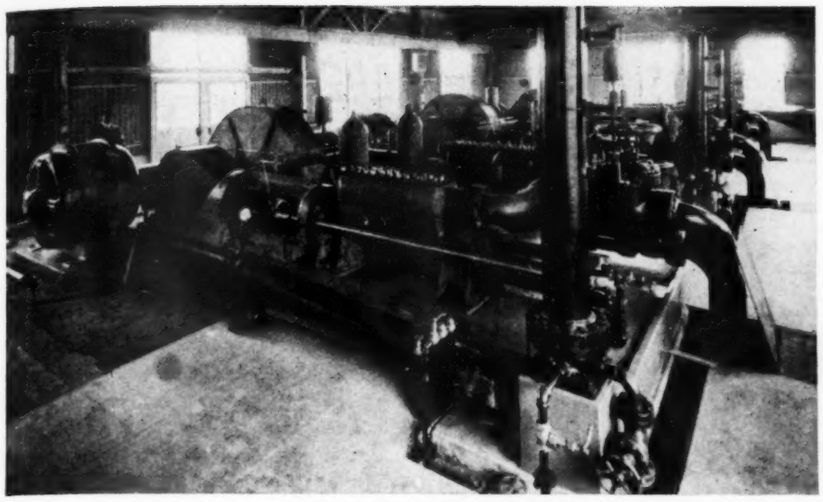
IN THE years 1925-29 a great increase in the number of crude oil pipe lines and in the total capacity of such lines was brought about by oil field discoveries of great magnitude, requiring large volumes of oil to be transported from West Texas, Seminole, and Oklahoma City, to existing markets. Another factor, tending to increase pipe-line facilities during this four-year period, was the loss of eastern markets by a large common carrier, whose originating stations were in Oklahoma and Kansas, due to having no refinery at its Great Lakes destination nor pipe-line facilities to serve such a refinery, if built.

The ultimate effect of these field discoveries and of natural economic trends forcing other refineries to pump their own oil was to give impetus to the construction of 2010 mi. of trunk pipe lines, having daily capacities of 210,000 bbl., representing the installation of 29,100 hp. of electric motors as prime movers for the movement of crude oil to the Great Lakes and to the Gulf Coast area. Another crude oil trunk pipe line company, pumping to the Great Lakes district, desiring to increase its capacity from 50,000 to 75,000 bbl. per day, resorted to electric motors as prime movers, totaling 14,400 hp. installed in nine booster stations. The total of 43,500 hp. of motors was used principally to operate 1800-r.p.m. centrifugal pumps; in fact, only 4500 hp. of the total motors operated plunger pumps, or about 10 percent of the total. Prior to 1929, however, and beginning in 1925, there were installed 122,400 hp. of electric motors to operate crude oil pipe-line stations, principally for intrastate service in Oklahoma, Texas, and Kansas. The ratio of plunger pumps to centrifugal pumps installed in this four-year period was 39 percent plunger to 61 percent centrifugal, as determined by a survey made early in 1930. The reason for the number of plunger pump installations being made during that time was due to several factors. One was the reluctance of the operator to accept centrifugal pumps for this service after having operated plunger pumps for so many years; another was the desire on the part of the pump manufacturer to proceed cautiously in the fabrication of centrifugal pumps after being in the business of building plunger pumps for so many years. Of secondary importance was the relative overall poor efficiency of the 1800-r.p.m. centrifugal pump, which was the maximum speed the manufacturers cared to use for the high pressures of 700 to 800 lb. per sq. in. usually required in this service.

W. H. STUEVE

received both mechanical and electrical engineering degrees from Ohio State University—Is a member of the Oklahoma State Board of Registration for Professional Engineers—Member of the American Society of Mechanical Engineers and American Petroleum Institute—For the last 15 years he has been associated with the Oklahoma Gas and Electric Company, having charge of oil-field, pipe-line, and refinery electrification—Recently he had added to his duties that of manager of the Department of Industrial Development.

Investigations and tests conducted on both types of pump stations, after being in service a year or more, disclosed the overall efficiency of 1800-r.p.m. centrifugal pumps, for station capacities of 30,000 to 40,000 bbl. per day, barely attained 60 percent; whereas, plunger-pump stations of similar capacity obtained overall efficiencies of 90 percent or slightly higher. The fixed charges, however, on the greater first cost of the plunger pump station over the fixed charges on the first cost of a centrifugal-pump station of comparable capacity, usually overcame the efficiency differential under average capacity-factor conditions of operation. From this viewpoint, the motor-driven centrifugal-pump station still held a slight advantage over the plunger-pump station.



Plunger pumps driven by induction motors

Thus, in passing through the four-year period (1925 to 1929) to the period through 1929 to 1931, the plunger pump for trunk-line service almost disappeared. Pump manufacturers in the meantime had perfected designs and had overcome metallurgical difficulties to such an extent that they were able to show overall efficiencies of 75 percent (pump and motor), by doubling the former speed from 1800 r.p.m. to 3600 r.p.m. when capacities of 30,000 to 40,000 bbl. per day were considered.

The year 1932 left no doubt in the minds of the pipe-line station designer as to the supremacy of the high-speed centrifugal pump over the low-speed centrifugal, and also the plunger pump. In 1932, the East Texas field was developed, resulting in the installation of 1017 mi. of trunk pipe line and 15,200 hp. of electric motors, providing a capacity of 339,000 bbl. per day to Gulf Coast terminals. All pump stations on these pipe lines were equipped with 3600-r.p.m. motor-driven centrifugal pumps, with the exception of three 600-hp. electric-motor-driven stations on one trunk system. These electric-motor-driven plunger pumps, for the one trunk line mentioned, were originally purchased and installed in 1929 as spare units in another trunk line pumping from West Texas to the Gulf Coast. The electric motor maintenance, during four years' operation, was found to be so low, and of practically no operating hazard, that the decision was reached to use the spare motors from the West Texas line as the prime movers for the East Texas pipe line; and, further, spare or standby pumping units were not considered as being necessary in the latter line.

About this time (in 1931), the first large gasoline trunk pipe line, which had been installed in 1929, required an increase of 50 percent in capacity to meet market demand. The original capacity was designed for 24,000 bbl. per day for an 8-in. line from Oklahoma refineries to distributing centers in Iowa, the gasoline being pumped by Diesel engines operating plunger pumps, but the increase of 12,000 bbl. per day, desired in 1931, was gained by installing 3600-r.p.m. induction-motor-driven centrifugal pumps. These units installed for booster purposes totaled 7700 hp., which included seven 400-hp. booster stations installed on 6-in. trunk line laterals, and were of special construction to permit outdoor installation and thus to reduce investments.

A rather unique design incorporated in the pumping unit provided for passage of the relatively cool liquid (gasoline) around the motor housing from the suction side before the liquid passed into the pump suction, which permitted a gain in several points of motor efficiency above that usually obtained from a conventional 3600-r.p.m. induction motor. This design arrangement, however, has not received a very wide acceptance in the industry, and the conventional practice of installing two air-cooled, explosion-proof motors in centrifugal pump stations still is considered by most pipe-line designers the most ideal practice, when considered with respect to flexibility, efficiency, and economic operating value.

In summarizing the electric-motor-driven pumping stations installed by trunk pipe lines, during the eight-year period, 1925 to 1932, the general acceptance of the 2-pole, 3600-r.p.m., induction motor, direct coupled to the 3600-r.p.m. centrifugal pump, can be noted from Table 1.

To denote the acceptance of electric-motor-driven pumping stations, it is of considerable interest to note from Table 1 that the 66,400 hp. of installations made during the period 1929 to 1932, represents almost 75 percent of the total prime mover horsepower installed for pipe-line service in that four-year period; further, the total electric horsepower shown (188,800), represents about 25 percent of the total power capacity used in trunk pipe-line stations in the United States prior to that time.

During the eight-year period (1932-40), the crude oil pipe-line station installations consisted principally of booster pumps to gain capacity increases by the trunk lines operating from East Texas to the Gulf Coast area, totaling about 4000 hp.; however, during this same period gasoline pipe-line installations increased greatly.

The apparent success obtained by refiners and marketers in the first years from the operation of the original gasoline pipe line from Oklahoma to the Great Lakes district, resulted in the decision to market gasoline in the same manner in the eastern territory.

Aside from the original trunk gasoline pipe line, consisting of 1237 mi. of 6-in. and 8-in. lines installed in 1929, there have been installed almost 5500 mi. additional pipe lines by some 15 companies to transport gasoline to their existing markets.

Probably the greatest amount of gasoline pipe line construction was in 1933, involving 1924 mi. of 6-in. and 8-in. lines, by three refining companies producing gasoline at eastern tidewater and desiring to reach markets in Pennsylvania, New York, and Ohio. The prime movers used by these systems were principally 3600-r.p.m. centrifugal pumps driven by electric motors.

The total motor prime-mover capacity installed by these three refining companies, for pumping gasoline from Bayonne and Marcus Hook, New Jersey, west and north to their market centers, was 14,575 hp.

In succeeding years after 1933 some 3500 mi. of additional pipe lines were installed for gasoline delivery, which

required 4200 hp. of motors driving centrifugal pumps at a speed of 3600 r.p.m.

In summarizing, prior to 1932 the total electric-motor capacity installed for trunk crude oil and gasoline transportation totaled 188,800 hp., and during the period 1932 to 1940, a total motor capacity of 22,775 hp. was installed, bringing the total to 211,575 hp.

TABLE I

Horsepower of pump stations and types of pumps installed from 1925 to 1932

Installation Period	Electric motors Installed, total hp.	Percent of total electric horsepower operating		
		1800-r.p.m. centrifugal pumps	3600-r.p.m. centrifugal pumps	Plunger pumps
1925 to 1929.....	122,400	46	15	39
1929 to 1931.....	43,500	40	50	10
1931 to 1932.....	22,900	0	92	8*
Total hp.....	188,800			

*Originally installed in 1929 as standby units.

Types of Electric Motors Used

In studying the types of electric motors placed in service during this 15-year period, the small number of synchronous motor installations is very noticeable. Only one company, which had a total of 9525 hp. of motor-driven pumps in use, saw fit to install 4500 hp. of slow-speed (514-r.p.m.) synchronous motors to operate plunger pumps through reducing gears. One other pipe-line company made use of synchronous motors in installing booster stations on an existing pipe line.

Each station was equipped with three 800-hp., 3600-r.p.m. synchronous-motor-driven centrifugal pumps; one of these units was to act as a standby for either of the other two units. The viewpoint of the designers, to justify the somewhat greater first cost of the synchronous motors over the conventional induction-type motor, was that the synchronous motors inherently were of higher efficiency by approximately 2 to 4 percent. This was true, and the slightly lower power bill, when considered on a 90 to 100 percent operating time basis, would have repaid the increased investment of the synchronous motors in three to four years.

It has been found, however, that the average operating time of most pipe lines, taken as a whole, is only of the order of 40 to 50 percent over a period of years, thereby extending the time to perhaps seven or eight years in which the difference between the first cost of the synchronous motor over the induction motor could be repaid.

Another type of electric motor installed was the so-called slip-ring motor, as it is commonly known because of its variable speed characteristics. One gasoline pipe line in the East adopted this practice rather extensively by equipping each station with one variable-speed motor-driven centrifugal pump of full capacity at full-rated speed but capable of delivering only one-half the total line pressure required at full-rated speed. This variable speed unit served as the low-duty unit and was operated in series with a constant-speed induction-motor-driven centrifugal pump as the high-duty unit, having characteristics of providing one-half total line pressure required at full-line capacity. Undoubtedly, a slight saving in electric power could be effected, when decreased capacities were desired, over the conventional practice of throttling the discharge header gate when such decreased capacities were necessary. The history of gasoline pipe lines, however, in late years, disclosing a steadily increasing market for their product in all seasons, precluded the necessity of seeking economies in operations in this manner. In other words, both units are operated at full speed and capacity almost continuously.

Another variation in the practice of using variable-speed motors was an installation by a crude oil pipe line wherein a small variable-speed motor-driven centrifugal pump of about one-seventh the ultimate pressure rating of the line was installed in the suction line of the station to act as a booster. The main pumping units were the conventional, constant-speed induction-motor-driven centrifugal pumps.

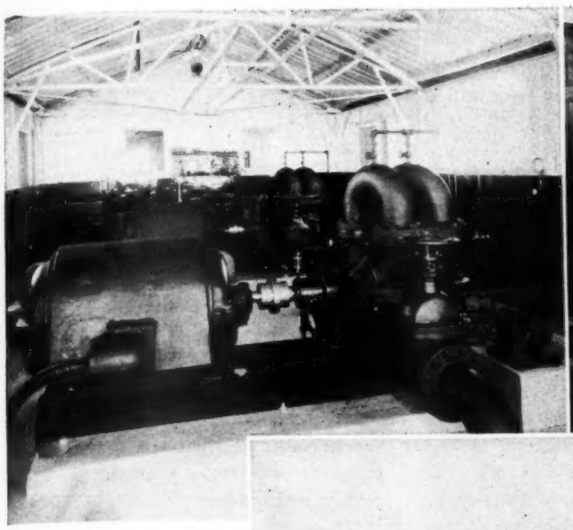
This arrangement acted as a throttle for decreased volumes on the suction and had the advantage of keeping the main pump units properly filled to prevent cavitation and also improved the mechanical efficiency of the main pumps. To indicate the trend of design practice, it may be said that because the synchronous motor and the slip-ring (variable speed) motor represent only about ten percent of all installations of electric motors for trunk pipe-line service, the selection of the constant-speed induction motor represents the best design practice.

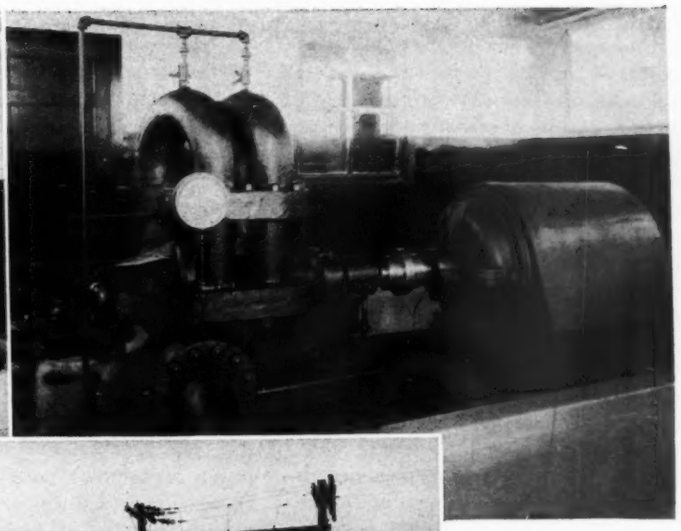
Motors selected in recent years for pipe-line service seem to bear out this conclusion. The 3600-r.p.m. induction motor is practically as efficient as the synchronous motor and requires less maintenance, thus justifying its selection.

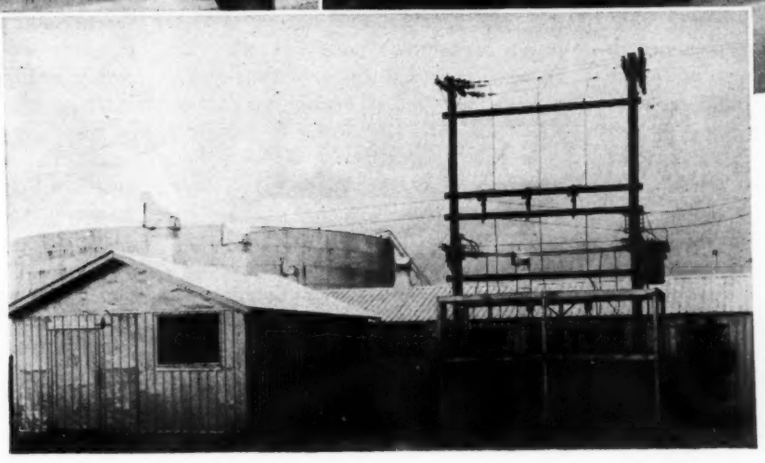
3600-r.p.m. centrifugal pumps driven by induction motors

Electric Motor Maintenance

An attempt to survey the cost of motor maintenance by means of a questionnaire sent to the principal users







• (Above, left) The original two 400 HP, 3600 RPM electric motors in service several years in West Texas.

• (Above, right) A third 400 HP, 3600 RPM motor added two years ago to the original installation.

• (Left) Exterior of the above station showing housing equipment and three 333½ KVA transformers and spare.

The Trend in Pipe Line Pumping is Toward PURCHASED ELECTRIC POWER

• Pipeline operators look at several things when they plan a new station—among them being the initial investment, fixed charges, salvage value, speed of installation, adaptability to automatic control, flexibility, portability and dependability. And that is why the trend is toward Purchased Electric Power—the investment is low, fixed charges are low, installation time can be figured in days rather than months, operating costs are low, the power supply is dependable and additions to the station capacity can be made easily and quickly.

Pipeline operators in the service area of the Texas Electric Service Company are invited to call on our engineers to aid in the solution of their power problems.

TEXAS ELECTRIC SERVICE COMPANY

of motor-driven pumps in transportation service, met with considerable difficulty, in that proper records are not kept in all instances that would permit such analysis. All repair costs to both motors and pumps are consolidated under one item, and in most cases it was found the motor portion of repair costs could not be segregated from the pump repair costs. Some information, however, was obtained from operators upon which can be based certain conclusions.

It has been the practice of engineers to asssume such motor repair costs at 25 to 50 cents per hp. per year when making operating cost statements to compare with other types of prime movers. In a sense, this could prove to be an erroneous assumption, as this method does not take into account the operating time element when individual motors are considered.

The management of one large company using electric motors extensively, reported that in their experience, the assumed repair costs should not exceed 25 cents per hp. per year, and, in fact, at a great many stations the repairs to motors amounted to only 2 cents per hp. per year for motors equipped with sleeve bearings, of relatively slow speed (720 to 900 r.p.m.), which were used to operate plunger pumps. In cases where 1800- and 3600-r.p.m. induction motors were installed, it was found necessary to renew the ball bearings generally only once a year, depending on the operating time element. The renewal of these ball bearings for motors of the class 200 to 400 hp. at 3600 r.p.m. cost about 30 cents per hp. as an average. Renewals of sleeve bearings in high-speed motors can be effected at a cost of about 10 cents per hp. of capacity. As about 90 percent of the larger high-speed motors in use for transportation service are of the sleeve-bearing type, and experience has shown that renewals are necessary perhaps only once in ten years, the cost for maintenance appears to be only 1 cent per hp. per year.

The management of another company that uses electric motors extensively in pipe-line service stated that their maintenance costs on the slower-speed motors were practically nil, the motors, at frequent intervals, requiring cleaning with air only and painting or varnishing the coils. Their high-speed motors, being equipped with sleeve bearings, when properly aligned with the pump, required only routine maintenance at nominal cost.

A third operator of electric motors for pipe-line service, reporting on 40 large motors of all speeds and capacities in the range of 250 hp. and larger, which had been operating for ten years, stated their repairs would not exceed 20 cents per hp. per year; however, routine and preventive maintenance might double this figure.

A fourth operator reports the maintenance cost on their larger motors for pipe-line service is so small as to be almost negligible.

Thus, after analyzing all conditions of costs from four pipe-line operating companies, which have in use about one-third of all the motors employed in this service, it is found that costs vary from 1 cent to 40 cents per hp. per year, leaving an observer with the idea that a safe estimate would be the half-way point, or something of the order of 20 to 25 cents per hp. per year as being acceptable for comparative estimating purposes.

P 625.

Increasing the Capacity of Dust Scrubbers in Natural Gas Pipe-Line Systems

EXPERIENCED pipe-line engineers often find that the solution of some of the most difficult problems can be facilitated by reverting to the fundamental laws of physics. An example of this was involved in recent experiments to increase the throughput capacity of dust scrubbers on one of the larger natural gas transportation systems.

Described briefly, the scrubbers were of the type that comprise two chambers within a large pressure vessel; the two compartments are separated by a diaphragm or plate in which a so-called "whirler box," equipped with ports, imparts a whirling motion to the ascending gas. The gas to be cleaned is introduced to the lower chamber through an inlet pipe so that it impinges upon, and is intimately mixed with, scrubber oil. The gas containing the oil particles then rises through the "whirler box" and the centrifugal force imparted to the gas effects a separation of the oil from the gas. Oil is returned to the lower chamber through four 3-in. downcomer pipes.

Centrally situated in the upper chamber is a vertical screen section (made up of a number of wrappings of hardware cloth) through which the gas must pass in leaving the vessel.

Designed for a given capacity originally, the scrubbers worked satisfactorily until the throughput of the system and the gas velocity had increased to a point at which the scrubbers no longer would retain the oil.

The successful solution hinged principally upon a realization of the fact that the downcomers possibly were prevented from returning the oil to the lower chamber because of the excessive differential existing between the chambers. The readings obtained were sufficiently high to indicate that gas was undoubtedly seeking the easier path to the upper chamber represented by the downcomer pipes. This upper passage of the gas would, of course, effectively prevent any oil returning to the lower chamber.

After this line of reasoning had been established, the rather obvious solution appeared to be the installation of seals on the downcomers having a sufficient head to withstand the maximum differential pressure occurring. Seals in the form of thin-wall pipe sections, closed at the lower end, were installed around, and concentric with, the downcomer pipes. When filled with oil these seals were capable of withstanding a differential pressure equivalent to a 30-in. column of oil. A piping arrangement was provided so that the seals could be re-charged when desired.

Upon installation of the first seals for a trial run it was found that no carry-over occurred in a 48-hr. test, during which the gas throughput and the accompanying velocity were maintained at values much higher than were then required in normal operations.

The cost of installing these seals in all the scrubbers along the line represented only a small fraction of the cost of installing additional scrubbers, which had been discussed as the ultimate solution to the problem; thus, by visualizing the simple principles involved in the mechanics of the scrubbers, it was possible to suggest a means that effectively increased the capacity of the dust scrubber materially.

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● 2-Way or Double Pipe Line Induction Motor Driven 3600 R.P.M.

PETROLEUM ELECTRIC POWER ASSOCIATION

P 615.223
P 622.225
P 615.635.4

Bolted Couplings of Various Types Are Used In Pipe-Line Construction

BOLTED couplings have long been accepted as essential items in providing the flexibility believed to be necessary in constructing large diameter lines of considerable length. Recently, in certain quarters, it has been suggested that provision for expansion and contraction need only be the amount obtained by providing loops in a welded line as it is lowered-in the trench. This innovation in practice has not yet been accepted widely, however. Most of the companies are adhering to the combination method of alternately welding and coupling, with couplings joining either two or three 40-ft. lengths of pipe, welded into 80- or 120-ft. sections, respectively. At least four recent major gas-transmission construction projects adopted this type of construction.

United Gas Pipe Line Company, in constructing its 150 miles of 14-, 16-, 18-, and 20-in. line from the Monroe gas field, Louisiana, to Jackson, Mississippi, adopted composite construction coupling three 40-ft. welded sections of pipe. This line is designed for 800-lb. pressure. The coating machine used by United and shown in an accompanying photograph is not capable of coating the couplings as are some of the other machines now available.

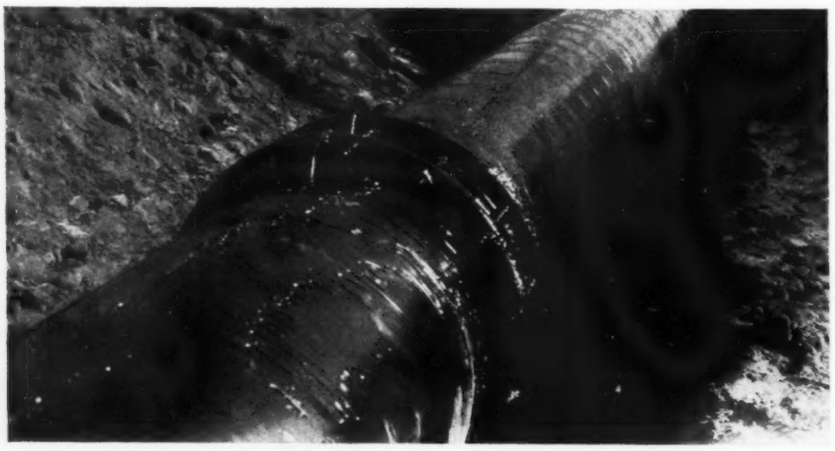
Southern Natural Gas Company, in its 32-mi., 18-in. line built from Onward to Yazoo City, both in Mississippi, coupled three 40-ft. sections that had previously been welded. This line is capable of operating at a maximum pressure of 425 lb.

Michigan Gas Transmission Corporation, the company serving Detroit, Michigan, with natural gas, welded two 38-ft. lengths of 24-in. pipe and joined the sections by couplings in the 15.3 miles of line built last summer. Maximum pressure on this line is 500 lb.

Panhandle Eastern Pipe Line Company in its extensive loop construction program now in progress, is coupling 80-ft. welded sections. Working pressure on this line is 500 lb. The nine loops between Liberal, Kansas, and Springfield, Illinois, comprise a total of 136.45 miles of 24-, 22-, and 18-in. pipe.

In the widespread application of the various methods being used to combat electrolytic corrosion of pipe lines, it is sometimes desirable to insulate sections of the line to prevent the passage of long-line currents; in other instances, particularly in cathodic protection, it becomes necessary to provide a path for the current across couplings by bonding metal to metal. It is now possible to obtain an insulating coupling of the bolted type for installations of the first type and a bolted coupling employing a special gasket providing a metal to metal bond between coupling and pipe, is available when a bond is desired.

Other recent developments in the design of bolted couplings include the use of a special inner coating suitable for cement-lined pipe now being adopted in salt-water disposal lines in East Texas and elsewhere. Of particular interest to pipe line companies is the new casing bushing used on highway and railroad crossings where the line must be cased. The bushing is easily installed and is a distinct improvement over the former method of welding-on coupling rings.



A bonded coupling painted and ready for lowering-in

Coating pipe on recently completed gas line

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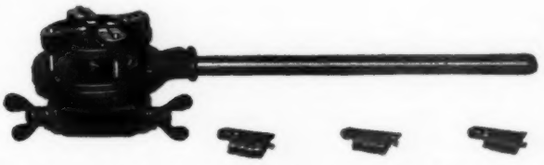

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Laws of Fluid Flow In Rough Pipes

Experimental work extends the determination of friction factor, f, into the region of flow conditions of existing high-pressure transmission lines

Part 1

By J. NIKURADSE

Perhaps no single work, since Weymouth's, has contributed so much of practical value to the knowledge of flow conditions in pipe lines as this paper by Nikuradse. Appearing in *Forschungsheft*, publication of Verein Deutsch Ingenieurs (German Society of Engineers) in 1932, it has been unavailable to American engineers except in the German version. Publication, even seven years after its appearance in Germany, is justified as an answer to the many requests from engineers in this country who desire to avail themselves of the data contained herein.

Due acknowledgment is hereby given to the Panhandle Eastern Pipe Line Company, 90 Broad Street, New York, New York, for permission to publish the English translation of the paper.

Introduction

MANY recent studies[1] have considerably increased our knowledge of turbulent flow in smooth pipes, channels, and along plates. Satisfactory results have been obtained regarding velocity distribution, law of resistance, exchange of momentum, and the mixing path, as well as the turbulent mechanism of these flows. But further progress demands an explanation of the laws of turbulent flow in rough pipes, channels, and along rough, flat plates. Owing to their frequent occurrence in engineering, the study of these problems is not only more important than a study of those concerned with flow along smooth walls, but is even of great interest in widening our knowledge of turbulent flow.

Turbulent water flow in rough tubes has been studied for about a hundred years by many investigators of whom the most important will be briefly mentioned. H. Darcy[2], one of the first to study the subject, made extensive, careful experiments with 21 pipes of wrought iron, lead, cast-iron, asphalted cast-iron and glass, in which the pipes (except the glass tube) were 100 m. long and had a diameter of 1.2 to 50 cm. He noticed that in addition to the diameter of the tube and the gradient as factors, the nature of the wall was determinative for the quality of flow. If we express his results in modern terms and consider the dependence of the resistance coefficient λ on the Reynolds Number, Re, we find that according to his measurement, λ for a given relative roughness k/r (k = mean elevation of roughness, r = radius of tube) is a magnitude slightly variable with the Reynolds Number. ($Re = \frac{\bar{u}d}{\lambda}$ is based on the mean velocity $\bar{u}$ and the diameter of tube d; λ denotes the kinematic viscosity). By increasing the Reynolds Number the resistance coefficient is reduced and the slower the process, the greater the relative roughness. In some cases of roughness the resistance coefficient λ is independent of the Reynolds Number. At constant Reynolds Number, λ increases considerably with increasing relative roughness. One of Darcy's pupils, H. Bazin[3], then continued these experiments and from his own experimental material together with that of Darcy, he derived an empirical formula. This gave the quantity of flow dependent on the gradient and diameter of tube and was used until recently for practical calculations.

In 1914, R. v. Mises[4] succeeded in classifying all experimental results hitherto known from the viewpoint of mechanics of similarity. He thus discovered the formula, chiefly from the measurements of Darcy and Bazin in circular pipes, for the coefficient of resistance λ dependent on the Reynolds Number and relative roughness:

$$\lambda = 0.0024 + \sqrt{r/k} + \frac{0.3}{\sqrt{Re}}$$

which, near the critical Reynolds Number expands for small Reynolds Numbers as follows:

$$\lambda = (0.0024 + \sqrt{r/k})\left(1 - \frac{1000}{Re}\right) + \frac{0.3}{\sqrt{Re}}\sqrt{1 - \frac{1000}{Re}} + \frac{8}{Re}$$

v. Mises was the first to introduce the nomenclature "relative roughness" for the ratio k/r, in which k denotes the absolute roughness.

In 1911, T. E. Stanton[5] demonstrated the similarity of the flow through rough pipes. He investigated pipes of two different diameters that had two cross screw threads milled into their internal walls. In order to obtain geometrically-similar elevations of roughness, he altered the pitch and depth of the screw threads to the same ratio as the diameter of the pipe. He even compared the smallest and largest Reynolds Number obtainable with his experimental device for the same tube and afterwards the velocity distributions for various tube diameters. In the first case there resulted complete agreement of the nondimensional velocity profiles, whereas in the second case a small deviation occurred in the immediate vicinity of the wall. In this way Stanton

1. *L. Prandtl:* Turbulenz und ihre Entstehung. Tokyo-Vortrag. 1929, J. Aéronaut. Res. Inst., Tokyo Impérial University, No. 65 (193); *Th. v. Kármán:* Mechanische Ähnlichkeit und Turbulenz. Göttinger Nachr., Math.-Phys. Kl. 1930 u. Verh. d. 3. intern. Kongr. f. techn. Mech. Stockholm 1930, Stockholm 1931 Bd. 1 S. 94; *J. Nikuardse:* Widerstandsgesetz und Geschwindigkeitsverteilung von turbulenten Wasserströmungen in glatten und rauhen Rohren. Verh. d. 3. intern. Kongr. f. techn. Mech., Stockholm 1930 S. 239; *L. Prandtl:* Zur turbulenten Strömung in Rohren und längs Platten. Ergebn. d. Aerodyn. Versuchsanst. zu Göttingen, 4. Lief. 1932 S. 18; *J. Nikuradse:* Gesetzmäszigkeiten der turbulenten Stromung in glatten Rohren. VDI-Forsch.-Heft 356 (1932).

2. *H. Darcy:* Recherches experimentales relatives au mouvement de l'eau dans les tuyaux. Mémoires à l'Académ. d. Sciences de l'Institute impérial de France, Bd. 15 (1858) S. 141.

3. *H. Bazin:* Experiences nouvelles sur la distributation des vitesses dans les tuyaux. Mémoires présantés par divers savants à l'Académie des Sciences de l'Institute de France, Bd. 32 (1902) No. 6.

4. *R. v. Mises:* Elemente der technischen Hydrodynamik. Leipzig, S. G. Teubner 1914.

5. *T. E. Stanton:* The Mechanical Viscosity of Fluids. Proc. Roy. Soc. Lond. (A) Bd. 85 (1911) S. 366.

Fig. 1. Resistance coefficient dependent on Reynolds Number for wall roughness

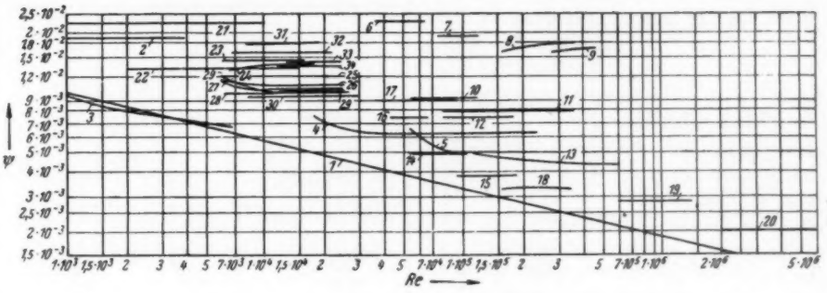
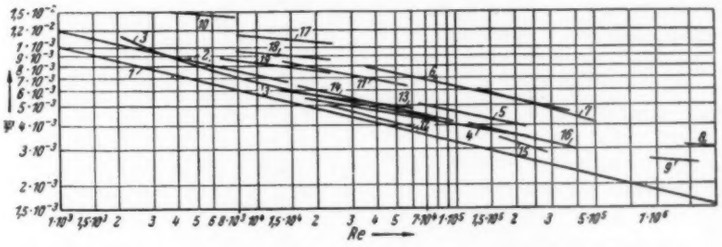


Fig. 2. Resistance coefficient dependent on Reynolds Number for wall waviness



demonstrated the similarity of flows through rough pipes.

More recently L. Schiller[6] made some further discoveries regarding the dependence of the resistance coefficient λ on the Reynolds Number and the nature of the wall, carrying out his measurements with drawn brass tubes. He produced the roughness, as accurately as did Stanton before him, by cutting threads of different depth and pitch in the experimental tubes and he changed the diameters of the tubes from 8 to 21 mm. As a result of his measurements it was found that the critical Reynolds Number was independent of the nature of the wall. He also established that at very large roughnesses the quadratic resistance curve is produced immediately after turbulence takes place. At finer roughnesses he found a slow rise in the resistance coefficient together with the Reynolds Number. Schiller was unable to determine whether this increase for large Reynolds Numbers passed to the quadratic resistance curve as the experimental devices then at Göttingen only reached to about $Re = 10^5$. He also found that at constant Reynolds Number the resistance coefficient λ increases with increasing roughness.

L. Hopf[7] then undertook another experiment, almost at the same time as Schiller, to determine the function $\lambda = f(Re, k/r)$. He performed systematic experiments in rectangular channels of varying height and at different stages of roughness (wire net, serrated

6. *L. Schiller:* Uber den Strömungswiderstand von Rohren verschiedenen Querschnitts und Rauhigkeitsgrades. Z. angew. Math. Mech. Bd. 3 (1923) S. 2.

7. *L. Hopf:* Die Messung der hydraulischen Rauhigkeit. Z. angew. Math. Mech. Bd. 3 (1923) S. 329.

SHEEHAN

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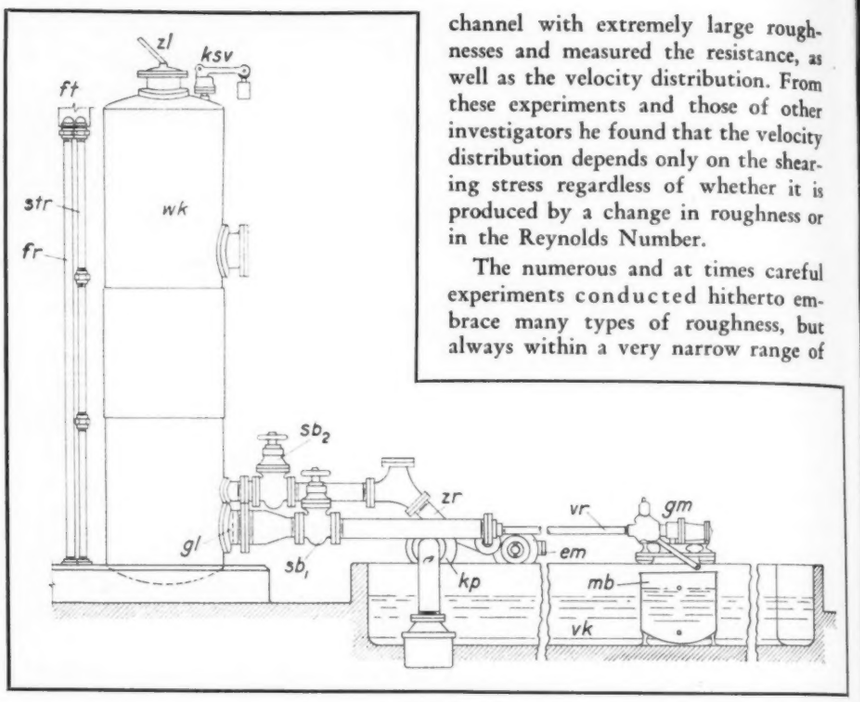


Fig. 3. Apparatus used in the experimental work

sheet zinc, two kinds of corrugated sheet iron). He chose a rectangular cross-section in order to establish the effect of the profile radius in the case of the small wall character by changing the height of the cross-section (profile radius, r′ = cross-sectional surface by wetted perimeter). At Hopf's suggestion these experiments were extended by K. Fromm[8]. From his own experiments and those of Fromm, as well as from other known experimental data, Hopf drew the conclusion that in the case of turbulent flow in rough pipes two types of roughness must be distinguished. These obey two distinct laws of similarity, which he called wall roughness and wall waviness. The roughness of the wall is so characterized by Hopf that the fall in pressure is independent of the Reynolds Number and entirely dependent on the nature of the wall (quadratic resistance curve). The waviness of the wall, according to Hopf, occurs when the coefficient of resistance is dependent on the Reynolds Number as well as on the character of the wall in such a way that in logarithmic plotting, the curves λ, as a function of the Reynolds Number for different wall characters, run parallel to the smooth curve. If the mean elevation of roughness be represented by *a* and the average distance from the two elevations of roughness by *b*, then the waviness of the wall at low values becomes *a*/*b* and the roughness of the wall at high values *a*/*b*.

On combining the investigations of Hopf, Fromm, Darcy, Bazin, and others, we find that Fig. 1 shows the roughness of the wall, and Fig. 2, the waviness of the wall. Hopf finds the empirical formula for the coefficient of resistance λ at wall roughness to be:

$$\lambda = 0.04\ (k/r')^{0.314}$$

in which r′ denotes the hydraulic radius of the channel ($r' = \frac{2F}{U}$ where

F = cross-sectional surface; U = wetted perimeter). This formula holds good for iron pipes, cement, waffle sheet, and wire net. For the waviness of the wall Hopf gives the formula:

$$\lambda = \lambda_0 \xi$$

in which λ_0 denotes the coefficient of resistance for a smooth wall and ξ a factor of proportion, ranging from 1.5 and 2 for wooden pipes and from 1.2 to 1.5 for asphalted iron pipes.

In addition to the coefficient of resistance the dependence of the velocity distribution on the nature of the wall is also important. Such measurements were carried out by Darcy, Bazin, and Stanton, but they lacked the necessary data on the temperature of the fluid, character of the wall, and fall in pressure. Recently, on the suggestion of v. Kármán, these measurements were repeated by Fritsch[9] with the same experimental devices as employed by Hopf and Fromm. The length of the channel measured 200 cm., the width, 15 cm., and the height lay somewhere between 1.0 and 3.5 cm., so that a two-dimensional flow took place along the short axis of symmetry. Fritsch investigated the velocity distribution at the following wall characteristics: 1. smooth, 2. wavy, 3. rough I (floor, glass plates with slight waves), 4. rough II (fluted glass), and 5. indented (illustrated with saw-profile by Fromm). Fritsch found that the velocity distributions at the same channel height, apart from a partitioning layer, are congruent for all these wall characters, as soon as the fall in pressure is the same.

Treer[10] made some experiments in a channel with extremely large roughnesses and measured the resistance, as well as the velocity distribution. From these experiments and those of other investigators he found that the velocity distribution depends only on the shearing stress regardless of whether it is produced by a change in roughness or in the Reynolds Number.

The numerous and at times careful experiments conducted hitherto embrace many types of roughness, but always within a very narrow range of Reynolds Numbers. On the other hand, our purpose is to study the effect of large and small roughnesses at all Reynolds Numbers and establish the laws proceeding therefrom. It was, therefore, necessary to investigate and determine a definite relative roughness r/k in a large range of Reynolds Numbers, whether at the constant r/k, therefore geometrical similarity, the values λ = f (Re) also yield a single curve for various wide pipes. Furthermore, the question was concerned with whether the velocity distributions at equal values of r/k were similar and changed with the Reynolds Number, and whether the velocity distributions also at different values r/k were similar in the Kármán sense.

I should here like to express my profound gratitude to my highly esteemed superior, Prof. Dr. L. Prandtl, who has always aided me with his valuable advice.

Experimental Work

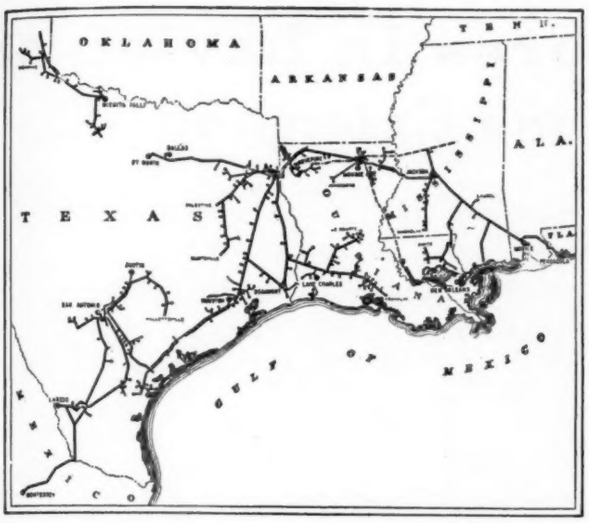
1. Brief description of the experimental device. The experimental plant employed in the experiments, as well as in studying the velocities of turbulent flow in smooth pipes was described in detail in Forschungsheft 356 of the Society of German Engineers, and is only briefly reviewed here. A sketch of the apparatus is shown in Fig. 3.

Editor's Note: This article will be continued in an early issue.

8. *K. Fromm:* Strömungswiderstand in rauhen Rohren. Z. angew. Math. Mech. Bd. 3 (1923) S. 339.

9. *W. Fritsch:* Der Einflusz der Wandrauhigkeit auf die turbulente Geschwindigkeitsverteilung in Rinnen. Z. angew. Math. Mech. Bd. 8 (1928) S. 199.

10. *M. F. Treer:* Der Widerstandsbeiwert bei turbulenten Strömungen durch rauhe Kanäle. Phys. Z. Bd. 9 (1929) S. 539; *M. F. Treer:* Die Geschwindigkeitsverteilungen bei gradlinigen turbulenten Strömungen. Phys. Z. Bd. 9 (1929) S. 542.



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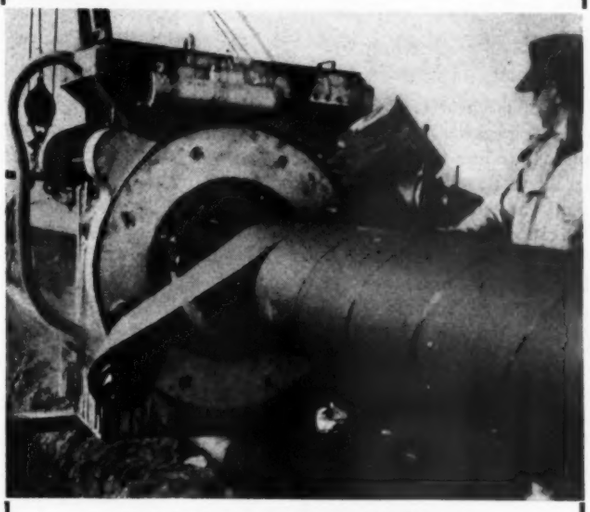

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By FRANK H. LOVE
Managing Editor

EXTENSION of Cimarron Valley Pipe Line Company's 6⅝-in. gasoline pipe line from Superior, Nebraska, to Rock Rapids, Iowa, gives that company a continuous line 516 miles in length originating at Enid, Oklahoma. The extension totals 262 miles and was laid in 59 calendar days, working conditions being marred only by intermittent high winds that hindered welding.

Two grades of gasoline, kerosine, and tractor fuel, manufactured at the Enid refinery of the Champlin Refining Company, are pumped through the line at a maximum operating pressure of 800 lb. and distributed from terminals at Superior, Nebraska, and Rock Rapids, Iowa.

Pumping facilities installed on the new section consist of small, compact units at Superior and Clarkson, both in Nebraska. At each station a single unit has been provided consisting of an 8-stage centrifugal pump driven by a 250-hp. motor, power being obtained from the utility companies serving these towns. The units are housed in galvanized sheet-iron buildings and are designed to operate at a maximum working pressure of 1000 lb. per sq. in., although the line is being operated at only 800 lb. The line has a capacity of 7000 bbl. per day.

At the Rock Rapids terminal two cone-roof and four floating-roof tanks, each having a capacity of 55,000 bbl., have been erected. At the terminal a brick warehouse has been provided, as well as facilities for loading tank cars and trucks.

Construction Features

Conventional methods of construction were employed in laying the line, the principal difference from similar projects being only the topography encountered.

Highlights of the work were the crossings of the Missouri and Platte rivers. The former was crossed at a point near Elk Point, South Dakota. Pontoons held in position by cables and anchors were used to buoy the pipe. Pipe sections were electrically welded on shore and pulled into the river by a barge and placed onto the pontoons. River clamps weighing 1000 lb. each and spaced every 20 ft., were of a design having a recess cast into them in which the waterproof telephone cable rests, thus providing a means of protecting the cable across the channel. Except for this one river crossing the telephone cable is supported on poles in the customary manner.

Line across Missouri River was supported by small barges as buoys until all was in readiness for lowering

The crossing at this point is 3900 ft. between normal water marks; in the shallow parts of the river the bed was dredged to a depth of 15 ft. When the pipe was in place an inspection was made by a diver, principally to determine if it contained "kinks."

The Platte River crossing, near Columbus, Nebraska, was 4500 ft. in width. The width of the Platte at this point is increased by the presence of an overflow canal from a hydroelectric plant. The pipe for this crossing was welded into two long strings that were pulled across the river by tractors and winch trucks. The river generally was shallower than in the Missouri River crossing and the use of pontoons was not required. Instead of dredging across the sandbars, existing because of the low water level, the pipe was "worked down" by workmen equipped with shovels. Telephone cable at this point was carried on an existing pole line.

Two spreads were used by the contractor in laying the line. Work began near the approximate center, one spread working toward Rock Rapids, Iowa, and the other toward Superior, Nebraska. The line was electrically welded, employing the stove-pipe method. The south half of the line was through fairly level country, as was the north half except for perhaps 30 miles on the bluffs of the Missouri River, which were rough and rolling. It was noteworthy that at no point on the line was it rocky enough to necessitate blasting.

The maximum amount of pipe laid by a single crew in a 9-hr. day was 22,000 ft. The average for each crew was about 18,000 ft. per day. For the most part weather conditions favored the workmen, the only hindrance be-

Laying approach to Missouri River crossing of 6-in. gasoline line

ing the high wind that at times delayed the welders.

Road and railroad crossing were cased with 8-in. pipe and, as requirements now are that in addition to concrete highways all gravel and country roads must be cased, a total of 8500 ft. of casing was used.

Scraper traps were installed at both stations and at an average of every 34 miles along the line. These traps were of conventional design except at the Missouri and Platte river crossings. At these points two small vertical tank-shaped strainers were installed to remove rust and other foreign material from the line and thus avoid the possibility of its settling in the sag in the river crossing resulting in stoppage or retarded flow.

Primer and coating were applied over the entire length of the line by traveling-type coating machines. The maximum speed of coating pipe by a single machine was seven miles per 9-hr. day. Felt wrapper was used only on the last 30 miles of the north section of the line because the weather was becoming extremely cold and this precaution was taken to prevent cracking of the coating.

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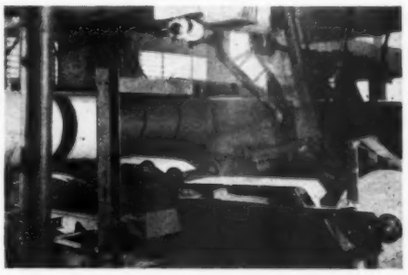

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Instructions for preparing bacterial cultures and for other work necessary in studies of this type of corrosion are given to stimulate widespread investigation by pipe line companies elsewhere

A PETROLEUM ENGINEER EXCLUSIVE FEATURE

PART I

By RAYMOND F. HADLEY
Electrical Engineer, Susquehanna Pipe Line Company

OF the many problems that beset the pipe-line engineer that of corrosion is probably the most unpredictable as well as the one about which the greatest controversy rages. The pipe-line engineer, to meet this problem of protecting his pipe lines against undue corrosion, has in turn employed other engineers with specialized knowledge in this field for the study and mitigation of the various kinds of corrosion found on his lines. In this study the corrosion engineer often becomes convinced that he has but one or two types of corrosion with which to deal, and as a result devotes his time to the study of these and excludes a study of other possible types. The direct result of this is the gathering of a vast amount of data relative to certain phases of the corrosion problem, with other types scarcely considered.

The writer at this time wishes to emphasize the fact that the microbiological anaërobic corrosion process is only one of the many types of corrosion ordinarily encountered in the field. Stray current electrolysis, acid, carbon contact, differential aeration, etc., are all ordinarily present on any pipe line of appreciable length, and particularly so in the eastern states, where the population density is high. It is the purpose of this article to present certain data relative to microbiological anaërobic corrosion, a process that has received practically no attention in the United States and yet one that the writer has found to be more common, and nearly as severe, than many other types of corrosion processes.

Papers[15, 16, 19*] relative to the microbiological aspect of corrosion have from time to time appeared in the various technical publications of several foreign countries. These papers have appeared, however, in such a diversity of publications that they are not readily available to the American corrosion engineer. Microbiological corrosion, either aërobic or anaërobic, is in reality much more conveniently studied by the bacteriologist or microbiologist than by the corrosion technologist. It is perhaps this fact that has led to its neglect by American corrosion engineers. There are, no doubt, many American corrosion technologists who have in the past believed that microbiological anaërobic corrosion was a foreign problem, if not a Dutch specialty. The error of such a view may be realized from an examination of the publications of Bunker[19] and Thaysen.[16]

*Figures refer to bibliography at end of the first installment of this article.

RAYMOND F. HADLEY

graduated in 1932 from the Rensselaer Polytechnic Institute with the degree of electrical engineer—Has been employed in the electrolysis department of the Susquehanna Pipe Line Company, Philadelphia, Pennsylvania, since that time—At present he is in charge of the electrolysis field work of the company.

Inspection Data

Some of the data obtained from surveys of eastern pipe lines give rather striking evidence concerning the extent and severity of anaërobic corrosion. The data presented in Table 1, show not only the percentage of test holes revealing bacterial attack, but also the percentage of pipe that re-

TABLE I

State and County	No. of test holes examined	Avg. distance between test holes, ft.	Avg. number of ft. of pipe examined per test hole	Percentage of test holes undergoing bacterial attack	Portion of total pipe requiring protection, due to bacterial attack, 1936-43, in percent
PENNSYLVANIA					
Delaware	30	1470	7.9	6.7	32.4
Chester	136	1120	7.5	12.5	38.1
Lancaster	113	1442	7.2	18.6	53.6
York	78	1886	6.4	20.6	70.9
Adams	162	905	6.3	25.3	43.3
*Franklin	102	936	6.2	41.8	96.6
*Cambria-Somerset	23	2004	6.2	26.0	32.0
*Westmoreland	135	1424	6.6	27.4	70.4
Allegheny	111	1536	7.2	26.2	79.2
Beaver-Lawrence	89	1626	7.5	41.5	61.1
*Schuylkill	82	640	7.7	14.6	20.1
OHIO					
Columbiana	7	1194	9.6	14.3	54.2
Mahoning	112	1507	7.6	51.7	80.2
*Portage	54	998	9.9	48.5	63.2
Summit	107	797	8.4	54.2	70.8
NEW YORK					
Onondaga	203	773	6.5	72.9	89.9

*Counties are not complete, i.e., test holes have not been dug from county line to county line.

Fig. 1. Uncovering pipe attacked by bacteria

quired attention due to this corrosion, thus giving some indication of its prevalence in certain eastern states where attention has been devoted to the problem. The test holes enumerated in Table 1 were dug in locations that were believed to be "hot spots" due to acid, carbon contact, or a degree of anaërobiosis that would permit microbiological anaërobic corrosion or differential aeration corrosion to take place. Further data that very forcefully illustrate the distribution of the sulphate-reducing bacteria throughout America are to be found in the publications of Bastin and collaborators [7, 8, 9, 10]. It is the hope of the writer that the data contained in this article will arouse sufficient interest among American corrosion technologists to promote investigations here in America to ascertain the extent and distribution of this type of corrosion together with perhaps some additional information as to the mechanism of the process. It is with this view in mind that the writer is including in this article certain information pertaining to the cultivation of the sulphate-reducing microörganisms together with certain analyses that may be carried out, which will conclusively demonstrate the presence or absence of bacterial corrosion. (Table 2.)

In a previous article[20] dealing with microbiological anaërobic corrosion a simple qualitative field test was described for indicating the presence of ferrous sulphide. This test was called the HCl test and is performed by collecting some of the products of corrosion from the pipe line in a test tube and adding to this a small quantity of hydrochloric acid. Liberation of H_2S, which can be readily detected by its odor, is taken as an indication of bacterial corrosion. As anticipated, the use of this simple qualitative field test was rather severely criticized. In behalf of this test, however, it may be stated that active enrichment cultures of the sulphate-reducing bacteria have been successfully grown from any location thus far tried along our pipe-line system where the presence of ferrous sulphide has been located either by laboratory analysis or by this HCl field test. It is, of course, obvious that a complete laboratory quantitative analysis of the products of corrosion on the pipe is much to be preferred over such a rough qualitative test. The ease with which this field test can be made, however, together with the excellent correlation that we have found between the results of this test and sites that are undergoing bacterial corrosion appears to justify its use.

Another point about which considerable controversy has centered, is whether or not the presence of ferrous sulphide among the products of corrosion found on the pipe is an actual indication of bacterial attack, as the ferrous metal of the pipe itself contains a small percentage of sulphur as an impurity, and it is believed by some that this sulphur may cause sulphide tests to give erroneous results. When consideration is given to the problem of whether or not the sulphur content of

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Fig. 2. View of pipe uncovered at site shown in Fig. 1

the steel itself would influence the HCl test we have the following data available: many chemical determinations of the impurities in the steel of our pipe line show the average sulphur content to be 0.0316 percent. In Chester County, Pennsylvania, 136 test holes were dug in locations that we believed to be favorable for the growth of the sulphate-reducing bacteria; that is, the largest single factor that seems to affect their growth was satisfied, namely, the locations were anaërobic. In all these 136 test holes only 12.5 percent showed FeS to be present by the HCl test, whereas 87.5 percent or 119 of the 136 holes gave no indication whatsoever of the presence of the products of corrosion in every test hole. Reference to Table 1 will illustrate the extremely wide variation in each county of test holes that do not show the presence of sulphide. It does not therefore seem commensurate with the facts to believe that the sulphur content of the pipe, which has a deviation of only plus 0.0174 percent and minus 0.0116 percent sulphur from the mean value of 0.0316 percent sulphur, could be responsible for the extreme variation of the sulphide content of the products of corrosion actually found in the field.

Typical quantitative analyses of the products of corrosion found on the pipe at three different locations where the pipe was subjected to active bacterial corrosion and at one location where bacterial activity was absent are shown in Table 3.

In the quantitative analysis of Table 3 it is of particular interest to note that the iron exists almost entirely in the ferrous state thus attesting to the

TABLE 2
Solution medium for cultivating sulphate-reducing bacteria.

Tap Water	1000 ml.
K_2HPO_4	0.5 g.
NH_4Cl	1.0 g.
Na_2SO_4	1.0 g.
$MgSO_4\ 7H_2O$	2.0 g.
*$NaC_3H_5O_3$	3.5 g.
$CaCl_2 2H_2O$	0.1 g.

DIRECTIONS:

Sterilize in an autoclave in convenient amounts and just before using, boil the medium and then cool rapidly to remove dissolved oxygen. Adjust the pH of the solution to approximately 7.5 before pouring in sterile 60-ml. ground-glass-stoppered bottles.

To each 60-ml. bottle add approximately 5-10 mg. crystal of Mohr's salt (Ferric ammonium sulphate, $FeNH_4(SO_4)_2 12H_2O$), after sterilizing in flame.

Use sterile methods. Transfers may be made using 1 ml. or less of the culture liquid. In making transfers it is generally desirable to include a quantity of the ferrous precipitate in the 1-ml. inoculum in the culture solution.

When this culture solution media is used for the salt tolerant or sea water strain it is necessary to add NaCl to the solution.

*As the commercially available chemical contains only 60 percent sodium lactate, multiply the quantity of sodium lactate specified above by 1.4.

a sulphide salt by this test. In other words, if the sulphur content of the metal itself could cause a sulphide test to give an indication of FeS from the products of corrosion in one test hole, it should give the same indication for

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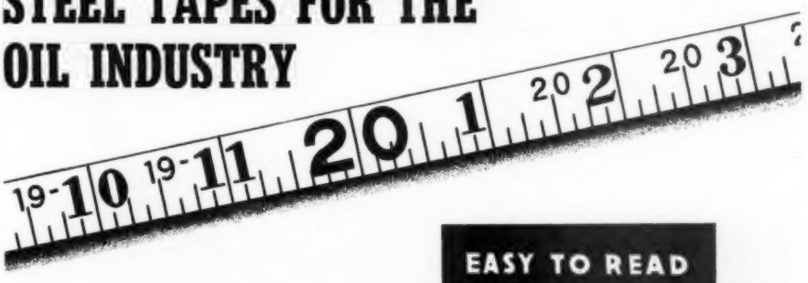

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degree of anaërobiosis. Note should also be made that the quantity of ferrous iron in combination as sulphide and carbonate is high; it is to be remembered in this respect that both H_2S and CO_2 are available as the result of bacterial metabolic processes. We have thus had the 0.0316 percent of sulphur in the ferrous pipe metal increased to 1.20-2.44 percent of sulphur in the ferrous corrosion salts. The problem thus is evolved: is this sulphur increase possible without additional sulphur being available from a foreign source? Previous investigators[1, 2, 3, 5, 6, 16] seeking to determine if the sulphur content of the ferrous metal itself could account for the quantity of sulphur found in the corrosion products have rather conclusively established the answer as negative.

TABLE 3

Analyses of dried samples. (Samples are each bluish-gray in color)

	Active bacterial corrosion			No bacterial corrosion
	No. 1, percent	No. 2, percent	No. 3, percent	No. 4, percent
Loss on ignition	15.9	17.7	28.8	13.8
Silicon calculated to SiO_2	26.8	35.0	8.7	49.9
Ferric iron calculated to Fe	0.1	1.4	2.1	5.0
Ferrous iron calculated to Fe	33.9	27.0	37.5	12.2
Aluminum calculated to Al_2O_3	5.8	7.1	3.9	7.9
Calcium calculated to CaO	None	None	1.1	1.3
Magnesium calculated to MgO	0.50	0.6	0.1	0.8
Sulphide sulphur calculated to S	1.71	1.92	1.15	None
Sulphite sulphur calculated to S	0.05	0.08	0.05	None
Sulphate sulphur calculated to S	0.30	0.44	None	None
Total Sulphur	**2.06**	**2.44**	**1.20**	**None**
Carbonate calculated to CO_2	8.4	10.6	18.0	11.0
Carbon dioxide calculated to ferrous carbonate	22.2	28.0	47.5	29.0
Ferrous iron calculated to ferrous carbonate	70.2	55.9	77.6	25.2
pH of water	6.8	7.0	5.8	7.2

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Test Methods

If the work of the investigators mentioned above and the analysis presented in this article be accepted as correct, a method for the determination of microbiological bacterial corrosion is available from a sulphide analysis of the corrosion salts. The writer believes, however, it advisable to check the sulphide analysis by actually growing cultures of the sulphate-reducing bacteria from the products of corrosion found on the pipe, because the conditions under which both bacterial corrosion and long circuit differential aeration corrosion proceed are identical and are often, if not always, found together. There is common agreement that the sulphate-reducing bacteria of the *Sporovibrio desulfurican* genera are strict anaërobes. This need not imply that the soil conditions for all degrees of microbiological corrosion must be uniformly anaërobic. Associations of aërobic and strictly anaërobic bacteria in decaying organic materials may create local zones where oxygen is completely absent that would be favorable to anaërobic microbiological corrosion. In practice it has been noted that at many locations along our pipeline system where the conditions are not sufficiently anaërobic to produce microbiological corrosion of a very serious degree, the sulphate-reducing bacteria may nevertheless be present at points where local anaërobiosis is fairly complete, such as aërobic soils where the bond between clods of earth and the pipe line is sufficiently intimate to exclude oxygen. Where such conditions are fulfilled the bacteria may be found by culture methods, but the minute quantity of ferrous sulphide available would indicate that they do not play

a predominant role as agents of corrosion at these points.

We have in practice found locations where the pipe has been pitted quite severely, principally along the bottom of the pipe. An analysis of the several factors contributing to the corrosion at this location showed the primary cause to be differential aeration, the pits being surrounded by large unaffected cathodic areas that were covered

TABLE 4

Organic compounds that can act as hydrogen donators in the process of bacterial sulphate reduction according to Prof. A. J. Kluyver.

Formic acid	Fumaric acid
Acetic acid	Glucose
Propionic acid	Mannose
Butyric acid	Galactose
Valeric acid	Saccharose
Heptylic acid	Maltose
Capric acid	Lactose
Palmitic acid	Ethyl alcohol
Stearic acid	Propyl alcohol
Succinic acid	Butyl alcohol
Aspartic acid	Isobutyl alcohol
Lactic acid	Ethylene glycol
Pyruvic acid	Glycerol
Glyceric acid	Erythritol
Tartaric acid	Mannitol
Citric acid	α-Hydroxy-butyric acid

with a relatively thick hard layer of Fe_2O_3 and yet in the anodic areas, along with the $Fe(OH)_2$ and FeO, were found traces of FeS. Culture media inoculated with bits of the ferrous salts from these anodic areas confirmed the somewhat surprising result of the HCl test. We believe the presence of the sulphate-reducing bacteria in these anodic areas was due only to the degree of anaërobiosis present at these points.

An analysis of the chemical compounds that exist in the anodic pit areas would undoubtedly yield considerable information in explaining bacterial growth at these points. The degree of anaërobiosis in each pit is no doubt fairly complete and it appears probable that the pH value in the pit is within those limits beyond which the activity of the sulphate-reducing bacteria would cease. If these first two requisites for bacterial growth are satisfied, it is reasonable to believe that the secondary factors may also be present in sufficient quantities to insure growth, for the $(SO_4)^{--}$ ions and the radical constituents of the organic acids, being anions, would migrate to these anodic areas. Bunker[19] has, in fact, made an analysis of the material found in a pit and found the contents to give a figure of 40.5 percent $(SO_4)^{--}$. Anaërobiosis of the pit would also be further insured by the bacterially formed H_2S ionizing to $(HS)^{--}$ and migrating to the anodic areas.

Many such variations are to be expected and are surely to be found if the investigator inspects an appreciable quantity of pipe, and it is only with practice that the investigator will be able to estimate readily the relative importance of bacterial or another form of corrosion in any situation. A study of many locations by investigators in this company indicates that only at locations where a strict degree of anaërobiosis prevails will the pipe be subjected to what can be called active microbiological corrosion. In these locations along with many deep wide-mouth pits the investigator will frequently find such large areas of the pipe corroded away that it will be impossible for him to make pit depth measurements without a specially constructed pit depth gauge. It is particularly significant to note that in practically every location thus far examined on our pipe line system where we consider the degree of anaërobiosis to be virtually complete, and where the other factors are likewise favorable

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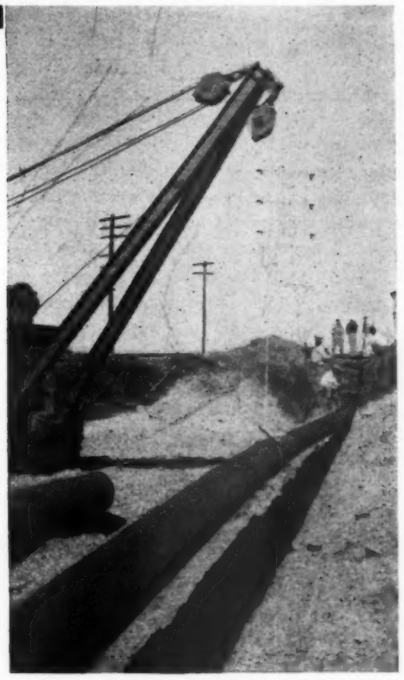

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for the activity of the sulphate-reducing bacteria, we ordinarily find the pitting factor to be unusually low and the ratio of uncorroded to corroded areas to be relatively small.

Actual measurements on pieces of pipe cut out of the pipe line in locations where the sulphate-reducing bacteria were particularly active showed the ratio of the uncorroded to corroded area to be 1.611 (Station 200 + 00, Summit County, Ohio, 3-in. Akron Spur), the uncorroded to corroded ratio being determined from one 12-in. axial measurement of a typical piece of corroded pipe. Two other measurements of the uncorroded to corroded area ratio made on 8.5-in. and 7.0-in. axial measurements, of a typical piece of 6-in. pipe cut from the pipe line in a swamp undergoing active bacterial corrosion gave figures for the ratio of 0.805 and 0.447, respectively. Our experience seems to indicate that the corroded area of the pipe, in locations that are undergoing active bacterial corrosion, is correlated with the degree of anaërobiosis of that location.

As mentioned previously, it has been repeatedly observed by several investigators of this company that the pits and slabs in locations undergoing active bacterial attack are all generally of very much the same depth. In order to substantiate this observation all pits and slabs included in each area for which the ratio of uncorroded to corroded area was determined were measured and the pitting factors corresponding to each area computed, giving values of 1.6, 1.7, and 1.8, respectively. *The data submitted herein relative to the ratio of uncorroded to corroded areas and the pitting factors are not by any means to be taken as a basis for any further computation.* The pipe areas from which these data were obtained are of necessity very small, having been determined from representative samples of bacterial-corroded pipe stored in the laboratory, and are included in this article only as an indication of magnitude as they are typical sections of the pipe actually removed from our pipe line. Many other measurements of similar sections would undoubtedly show a considerable deviation from these values; however, the writer believes that insofar as visual observation can be relied upon, these sections may be considered as representative.

Factors of Bacterial Activity

There are many factors that will influence the growth of the sulphate-reducing bacteria—the degree of anaërobiosis and pH of the soil water being probably the most important. Certain organic compounds must also be available to satisfy the energy requirements of the sulphate-reducing bacteria, and it is also necessary that a sulphur-oxygen salt be available[4] for the reduction process to take place. From these substances the sulphate-reducing bacteria are able to develop and produce H_2S and CO_2. Baars,[11] in his excellent dissertation, reports a great number of oxido-reduction balances for many different organic substances using several strains of the sulphate-reducing bacteria. He was thus able to conclude that the general reaction for the dehydrogenation of organic matter would take place in accordance with the following equation:

$$CpHqOr + (2p-r)H_2O \rightarrow pCO_2 + (4p - 2r + q)H$$

It is thus possible to write the oxido-reduction and carbon balances for the various organic compounds available to the sulphate-reducing bacteria as in the case of lactate ($C_3H_6O_3$) $p=3$, $q=6$, $r=3$.

$$C_3H_6O_3 + 3H_2O \rightarrow 3CO_2 + 12H$$

Twelve atoms of hydrogen thus are available, if complete oxidation occurs, for the process of sulphate-reduction. The substrate resulting from the dehydrogenation of lactate is acetate, ($C_2H_4O_2$), which on dehydrogenation yields eight atoms of hydrogen for the sulphate-reduction process, etc.

The varied list of organic substances available for use by the sulphate-reducing bacteria, to say nothing of the difference in concentrations of these substances that could probably be tolerated by the bacteria before bacterial activity ceased, must certainly indicate that any approach to the solution of a field problem by the study of the abovementioned factors would require years of research. Table 4 contains a list of specific organic compounds[12] already ascertained to be available as hydrogen donators to certain strains of the sulphate-reducing bacteria. This list numbers 32 specific organic compounds, and is not even then complete. In nature, certain of these organic compounds are available to the sulphate-reducing bacteria from sewage or through the decomposition or fermentation of cellulose and other compounds that may exist as wood or other vegetable debris. The diverse organic compounds formed as products of decomposition processes brought about by the numerous microörganisms in the soil include many of the compounds that can be utilized by *Sporovibrio desulfuricans.*

Frequently in pipe-line construction, wooden skids, tree trunks, branches, miscellaneous vegetation, etc., are thrown in the trench on top of, or beside, the pipe and then covered with the backfill. If construction of this type is carried out at a location where a fairly high degree of anaërobiosis can be maintained in the soil with the various other factors favorable for the growth of the sulphate-reducing bacteria, a failure at this site may be expected in a few years.

EDITOR'S NOTE: This article will be continued in an early issue.

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Recommendations for Stove-Piping and Roll-Welding Line-Pipe

Both stove-pipe and firing-line methods of welding are essential in line construction of certain types — tables of rod sizes and amounts, average speeds, spacing of joints, and amperages and voltages to be used, represent best practice

By C. M. TAYLOR
Vice-President, The Lincoln Electric Company, Cleveland, Ohio

"STOVE-PIPE" welding in pipe line construction had its origin in laying lines in rough, muddy or swampy terrain. Under such conditions, this method has been found to be less expensive than roll welding. Each joint is laid and welded individually. All welds are bell-hole, or position welds. As a line-up crew is eliminated, the cost of the welding is, of course, reduced. The reduction amounts to between 1 and 2 cents per ft.

In recent years, it has been shown that other conditions favorable to "stove-piping," besides rough, muddy or swampy country are (1) use of small size pipe and (2) use of lightweight pipe.

Progress of a "stove-pipe" job obviously depends upon the rate of digging the ditch as no joints can be welded by this method until the ditch has been prepared.

Lines constructed of 6-in. pipe should be "stove-piped" in all instances except where the ground is frozen. A welder can make nearly as many 6-in. welds in a day when position (stove-pipe) welding is employed as when roll-welding on a firing line. In some cases, this applies also to 8-in. pipe.

Tables 1, 2, 3, 4, and 5 give procedure data for pipe welding. Included are: sizes of electrodes for each bead (Table 1); average speeds of pipe-line welding (Table 2); amount of electrode used to weld various sizes of pipe (Table 3); spacing of pipe joints for welding (Table 4), and amperages and voltages for various sizes of electrode (Table 5). The tables give data for both "stove-pipe" and roll-weld procedures. Certain of these data appeared in tables of similar type accompanying an earlier article[1], but are revised now because of various changes in recommended practice.

Conditions under which roll-welding would be preferable in pipe line construction would be: (a) where the pipe is over 12 in. in diameter; (b) where the pipe is heavy; (c) where country

[1] "Welded Pipe-Line Construction Features Greater Use of 'Stove-Pipe' Method," by A. F. Davis, *The Petroleum Engineer*, Midyear, 1939.

***TABLE 1**

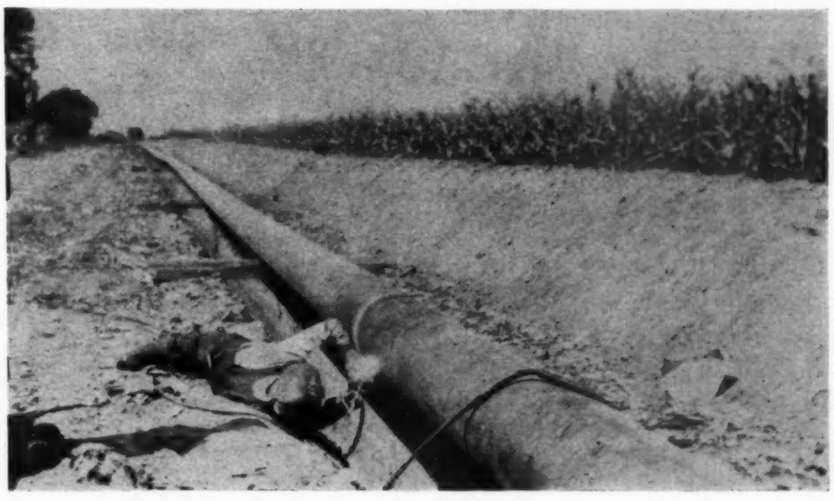
Electrode Sizes

Size pipe, in.	Stringer bead, in.	Second bead, in.	Third bead, in.
Roll-welding without backing-up ring			
4	5/32	3/16	1/4
6	5/32 or 3/16	1/4	5/16
8	3/16	1/4	5/16
10	3/16	1/4	5/16
12	3/16	1/4	5/16 or 3/8
Roll-welding with backing-up ring			
6	3/16 or 1/4	1/4	
8	1/4 or 1/4	1/4	
10	1/4 or 5/16	5/16 or 3/8	
12	1/4 or 5/16	5/16 or 3/8	
14	5/16	5/16 or 3/8	
16	5/16	3/8	
18	5/16	3/8	
20	5/16	3/8	
22	5/16	3/8	
24	5/16	3/8	
26	5/16	3/8	
Position welds without backing-up ring "Stove-pipe" or "tie-in" method			
6	5/32	3/16	3/16
8	5/32	3/16	3/16
10	5/32 or 3/16	3/16	3/16
12	5/32 or 3/16	3/16	3/16
Position welds with backing-up ring			

Use 3/16" rod for all beads on all sizes of pipe

C. M. TAYLOR

graduated from Western Reserve University in June, 1916—Went to work for The Lincoln Electric Company immediately following graduation and remained until the summer of 1917, when he entered the Air Corps Service — Returned from government service in January, 1919 — His first position was as clerk in the production department, then time study department, assistant superintendent, superintendent, and in 1928 vice-president in charge of sales — Serves on the board of directors of The Lincoln Electric Company.



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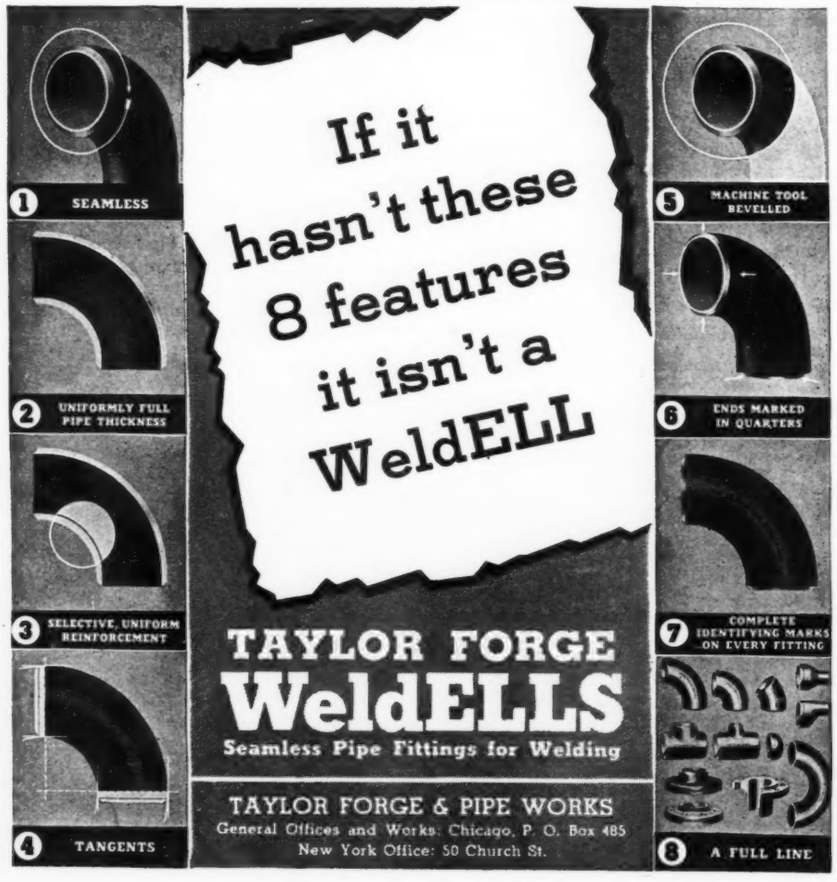
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is level with no obstructions, and (d) where nature of terrain, such as rocky or frozen ground, makes it difficult to dig the ditch.

Study of the procedure data given herewith will indicate that any effort to compare "stove-piping" and roll-welding from a cost standpoint must take into account the ultimate cost and any special considerations such as requirements for construction speed, time of completion, etc. Although the "stove-pipe" method is advantageous under the particular conditions referred to above, it might lose its advantage under the special conditions that are favorable to roll-welding.

Both methods of pipe-line welding—"stove-pipe" and roll-weld—are vital in pipe-line work. Each method suits its particular set of conditions best and the choice of either method should be on the basis of meeting the conditions.

Some recent arc-welded pipe-line construction projects are shown in the accompanying illustrations.

***TABLE 2**
Average Speeds of Pipe Line Welding

Roll-welding without backing-up ring (three beads)

Size pipe, in.	Average welds per hour
6	6.0
8	5.5
10	4.0
12	3.0

Roll-welding with backing-up ring (two beads)

Size pipe, in.	Average welds per hour
6	7.0
8	6.5
10	5.0
12	4.5
14	4.0
16	3.5
18	3.0
20	2.7
22	2.5
24	2.3
26	2.1

Position-welding (stove-pipe method) without backing-up ring
After first bead run by tackers

Size pipe, in.	Average welds per hour
6	5.0
8	4.0
10	3.0
12	2.0

***TABLE 3**
Amount of Rod Used to Weld Various Size Pipe
(Less without ring, due to close spacing)

Size pipe, in.	Lb. rod per weld with ring	Lb. rod per weld without ring
6	1	¾
8	1½	1½
10	1¾	1¾
12	2¼	2¼
14	2¾	
16	3	
18	3¼	
20	3½	
22	4	
24	5	

Arc-welding a joint in stove-piping method

***TABLE 4**

Spacing of Pipe Joint for Welding

Roll-welding without backing-up ring

Size pipe, in.	Average spacing, in.
4	1/8 to 1/8
6	1/8 to 1/8
8	1/8 to 1/8
10	1/8 to 1/8
12	1/8 to 1/8

Roll and position welding with backing-up ring

For all size pipe use a space of from 3/32" to 7/32".

Position-welding without backing-up ring

Size pipe, in.	Average spacing, in.
6	1/8
8	1/8
10	1/8
12	1/8

***TABLE 5**

Amperage and Voltage for Various Sizes of Rod

Roll-welding

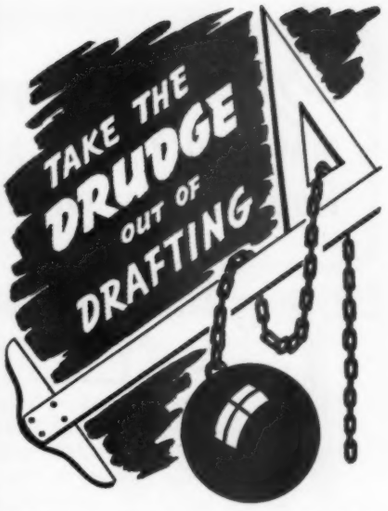
Size rod, in.	Amperage	Voltage
1/8	100-150	30-40
5/32	125-200	30-40
1/8	150-225	30-40
5/32	175-300	30-40
1/4	200-325	30-40
1/8	250-400	30-40
5/8	350-500	30-40

Position-welding

Size rod, in.	Amperage	Voltage
1/8	100-150	25-40
5/32	125-200	25-40
1/8	125-200	25-40

*Data from H. C. Price Company, electric welding contractors, Bartlesville, Oklahoma.

Lining up pipe for roll-welding



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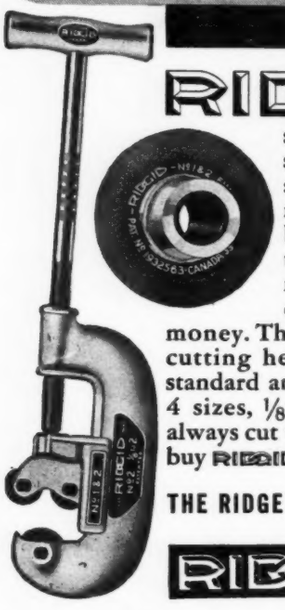

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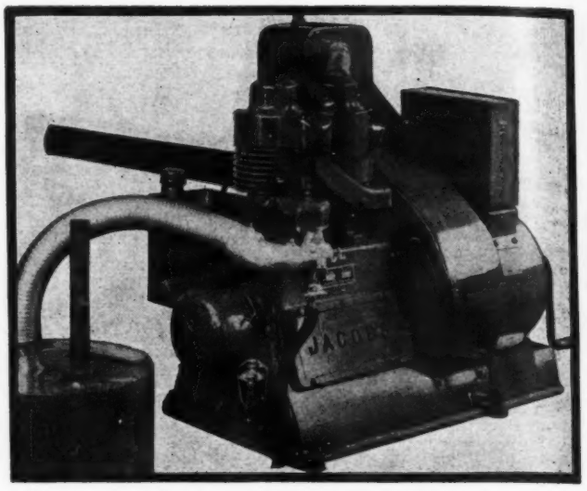

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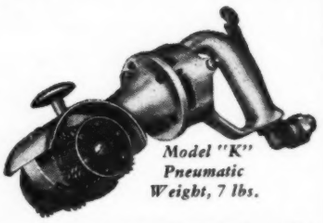

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Dehydration for the Smaller Natural Gas Pipe-Line Systems

When investment in modern, automatic dehydrating equipment is out of the question, small operator can obtain satisfactory results by using inexpensive, field-fabricated brine contactors or "bubble-pots"

By J. E. MOORE
Vice-President, Billings Gas Company, Billings, Montana

EVER SINCE the first use of pipes as a means of transporting natural gas, operators of gas systems have been more or less concerned with the problem of dehydration, although they have not always called it that. Wherever gas men have foregathered, the conversation sooner or later has centered on the subject of "drips", those wondrous devices designed to remove "moisture" from the gas, for moisture is the source of many troubles ranging from slow failure occasioned by internal corrosion to abrupt stoppage from freezing. The number of drip designs is almost equal to the number of men who have been obliged to use them. Some are simple traps to catch the already condensed liquids. Some are intended to assist in the condensing. Some are designed to utilize centrifugal force by giving the gas stream a whirling motion, whereas some obtain an impinging action by spraying the gas through perforations against the walls of the drip. Still others, and there are many of these, lead the gas through a maze or labyrinth of baffles and passages in the apparent hope that somewhere in its tortuous passage the gas will be able to "give the dodge" to its unwanted fellow traveler, the ubiquitous and persistent moisture.

Nearly every man who has had very many years of experience in the operation of natural gas lines has been puzzled at some time or other by the apparently unaccountable phenomenon of a gas line "icing" or "frosting" when the temperatures of the gas, of the pipe line, and of the atmosphere were all well above the normal freezing point. To complicate the problem still further, these freeze-ups have had a habit of occurring more frequently during the late winter and early spring months when the weather is much milder and the load much lighter than during the colder weather when little if any trouble is experienced. Installation of additional drips in the trouble zone seldom accomplished much in the way of relief and a "slug" of ice in the pipe line came to be accepted as a sign of spring, like the first robin.

Many also have had the experience of opening-up a gas pipe line that had been frozen-off and that could be isolated and drained, only to find that the slug of ice that had effectively shut-off the flow of gas through a sizable pipe line had left, upon melting, not more than a cupful of water. This led to a suspicion that something other than "free" water was at the bottom of the trouble, and many have been the more or less learned discussions concerning the cause of the "frost going down in the spring" and the disappearing act put on by the ice that would burn if you could catch it before it had melted.

J. E. MOORE

for 18 years has been in the employ of various gas companies affiliated with The Ohio Oil Company — He spent six months in the natural gasoline department of The Ohio Oil Company, for three years was local manager of The Rocky Mountain Gas Company in Wyoming, having added duties in care of field gas measurement and pressure-control equipment in Big Horn Basin fields, for four years was superintendent of distribution for the Billings Gas Company, superintendent of pipe lines for Gallatin Natural Gas Company, and from 1929 to 1933 was manager of the Billings Gas Company and superintendent of the Gallatin Natural Gas Company — Since 1933 he has been vice-president and general manager of the consolidated companies.

All of which has been a rather roundabout way of arriving at a point. Realizing that some means was needed for removing from gas the water that was in vapor form, and having in mind the fact that calcium chloride is an excellent drying agent, it occurred to some undisclosed genius to apply its drying action to gas flowing in pipe lines—and gas dehydration, as such, was born.

Interest in dehydration has grown rapidly as the work of Hammerschmidt and others has brought a better understanding of the character and causes of gas hydrate formation. Long, expensive gas lines traversing areas having widely different climatic conditions and necessitating greater accuracy in computing delivery capacities have made it imperative that every possible variable affecting capacity be eliminated, one of the most important of which is hydrates. The formation of hydrates is most apt to occur at a time when the gas load is greatest and when their adverse effect on the delivery capacity of the pipe line is most serious. Also, wide acceptance of gas for home and building heating and for many important industrial processes, considerations of public relations and good will, and the pressure of competition have added stress to the importance of continuity of supply and to the need for reducing the hazards of gas pipe-line operation to the absolute minimum.

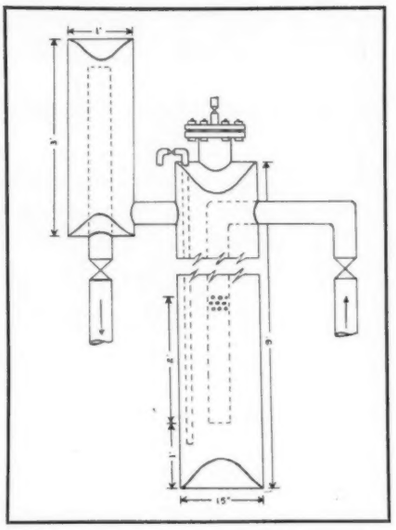
Engineers and chemists have responded to the need by supplying the pipe-line operator with better apparatus, better technique, better hygroscopic agents, and perhaps equally if not more important, simpler and more dependable methods of dew-point determination, so that it is now possible to control the water-vapor content and to put into the pipe line, gas with a known and closely controlled dew point. Many important gas lines operating under conditions favorable to the formation of hydrates have been, and are being, equipped with dehydration apparatus and, no doubt, many more

will be as the advantages become better known. Modern dehydrating plants are almost entirely automatic in operation and the unit cost is relatively low when the volume of gas handled is large and reasonably constant.

But right there is the catch for the small operator. He has exactly the same problems and it is just as important to him that he serve his customers well as in the case of the great "trunk" systems. Yet his volume is often insufficient to warrant the investment required for a modern, automatic, highly efficient dehydrating plant utilizing the latest synthetic hygroscopic chemicals. Also, there are many cases when at least partial dehydration is necessary or desirable to facilitate the movement of gas from the well to the large central dehydrating plant, and it is for the benefit of these small operators and special cases that this article will attempt to describe a simple, inexpensive, and quite effective type of dehydration that is coming into widespread use in Montana and Wyoming, where conditions are most favorable for hydrate formation and where relatively small gas systems are the rule rather than the exception.

For a good many years it has been a common practice in the oil fields of these northwest states to equip "vacuum" lines with calcium chloride dryers. These usually consist of a chamber in which is placed a basket of screen wire containing dry flake chloride. With the relatively small volumes of gas handled at consequent low velocities, contact with the chloride is complete enough for practical purposes and results obtained from the use of these simple dryers have been very satisfactory, so much so that attempts were made to apply the same principle to the drying of large volumes of gas. But when this was tried it was found that to keep velocities reduced to the value necessary to assure sufficient intimate contact with the dry chloride in the baskets, it was necessary to increase the containers to an impracticable size or number or both. Furthermore, when effective contact was obtained, efficiency fell off quickly because of the rapid "slaking" of the chloride and the attendant reduction in contacting surface, as well as glazing of the surface from partial saturation. Dehydration was only partly complete at best and under conditions of capacity flow when it was needed most, dew-point depression was only about 3 to 5 deg., or not enough to make the effort worthwhile.

The next development was the "bubble-pot," a simple type of brine contactor in which the gas is passed directly or "bubbled" through calcium



Brine contactor or "bubble-pot"

chloride brine. Its origin is not definitely known, although Mark Hardy, gas engineer for The Montana Power Gas Company, had a hand in its development as a practical device and was among the first to bring it to attention. A still later improvement has been the addition of a "knock-out" chamber to reduce the tendency for brine to be carried over into the line as sometimes happened when the gas flow was not steady, as from wells that are inclined to "head up" and flow periodically, and the result has been an increase of as much as 50 percent in capacity with no increase in the size of the main chamber or in the amount of brine required.

The pot shown in the accompanying sketch is made of 15-in. casing (or 16-in. line pipe). The connections are 4-in., the inlet pipe being carried to within about 1 ft. of the bottom, where the end is left open. About 2 to 2½ ft. above the open end, this pipe is perforated with ⅜-in. holes closely spaced and of sufficient number to obtain a combined hole area equal to that of the inlet pipe. The top of the vessel is fitted with a bolted flanged cover provided with a bleeder and of sufficient size to receive conveniently the charge of dry flake calcium chloride. A small bleeder line should extend from the top of the main chamber to below the center line to provide for drawing off excess brine and for taking samples of brine for testing. The 4-in. outlet pipe should enter the knock-out chamber near the bottom to facilitate drainage, and the outlet from this chamber should extend to within 2 or 3 in. of the top, so that the gas must rise and reverse its direction in leaving the chamber.

The entire assembly is set adjacent to the pipe line with some 3 ft. protruding aboveground. Installed on a bypass around a valve in the line, the gas may be directed through the dehydrator only when dehydration is needed. The initial charge is about 400 lb. of dry flake calcium chloride, to which is added enough water to submerge the perforations in the inlet pipe by a few inches. When this water is agitated it quickly becomes a saturated solution of calcium chloride and will remain thus so long as there is undissolved chloride at the bottom of the container. In this way the brine strength is maintained almost automatically, the dissolving chloride offsetting the increment of water as water vapor is absorbed from the flowing gas. Another automatic feature arises from the fact that the dew point resulting as the gas contacts the brine, varies as the temperature at which the contact occurs, so that the dew point of the treated gas is lowest when the temperature of the gas is lowest and the need for dehydration is greatest. To insure the gas being at a low temperature as it contacts the brine and also to assist in condensing the greatest possible amount of free water thus reducing brine dilution to a minimum, the gas is usually piped through a "cooler line" of increased diameter and of some length, to be discharged into a drip or trap immediately upstream from the chloride pot.

It is easy to check on brine strength by using an ordinary storage battery hydrometer. A sample should be drawn and tested soon after the unit is put into service, the reading obtained being used as a reference point. When periodic tests show an appreciable decline in brine strength, the brine level should be reduced to its original point by drawing-off the surplus and about 200 lb. of dry chloride added.

A bubble pot of this size will handle gas at the rate of approximately 200,000 cu. ft. per hour at 300-lb. pressure. For larger or smaller flows the size may be varied accordingly, about the only important thing being that the depth should be sufficient to minimize "slopping" of brine over into the line, and for the same reason the diameter should be such that the velocity of the gas stream is kept well under 200 ft. per min.

There is little need for apology to the engineering profession for the utter lack of scientific exactitude prevailing throughout this article. The omission has been intentional because it is not even suggested that the simple device described should take the place of more exact and efficient methods where they are to be had, and because its simplicity is the thing that it is desired to stress.

P 644.61
P 648.223

Protective Coatings On Aboveground Pipe-Line Structures

Coatings are now available to meet any required specific condition and give economic protection against corrosion and excessive evaporation loss

By C. F. RASSWEILER

Director, Philadelphia Laboratory, Finishes Division, E. I. duPont de Nemours & Company

ANY article dealing with paint protection of pipe line property must choose between the discussion of three distinctly different problems: first, the protection of the pipe line itself; second, painting the inside of tanks, and third, the painting of the exterior surfaces of the aboveground structures associated with the operation of the line. All three of these problems are related in that in each case the effort is to prevent rusting of the metal, but entirely different factors operate to destroy the protective value of the coating in the three different cases. This article will be confined to the least spectacular but vitally important third problem—that of protecting the exterior surfaces of aboveground metal structures associated with pipe-line operation.

A successful paint maintenance program must include careful attention to four factors: (1) Selection of material, (2) preparation of the surface, (3) proper application, and (4) adequate film thickness.

To select painting materials properly for any given purpose, a careful analysis must be made of the relative importance of the various properties desired and the destructive influences that the paint coatings must withstand. Even the most carefully selected material, however, will not give satisfactory results if proper attention is not paid to each of the other three factors. Interfering materials such as grease, rust, moisture, and partly corroded or loosely bonded millscale left on the steel at the time of painting prevents inhibitive pigments in protective coatings from coming into intimate contact with the metals they are supposed to protect; pockets are formed as a consequence, in which water can collect between the paint and the steel, causing early corrosion[1]. The paint must be applied under atmospheric conditions that will permit adequate drying and must be spread evenly so there are no thin spots at the plate edges or around rivets. A sufficient number of coats must be applied so that a covering of adequate impermeability is obtained and so that the gradual surface erosion resulting from weathering will not reduce the protective coating to an ineffective thickness, except after long exposure.

C. F. RASSWEILER

was educated at the University of Denver and the University of Illinois —Has been associated with E. I. duPont de Nemours & Company since 1924, first in the experimental station at Wilmington, Delaware; since 1927 in the fabrics and finishes laboratory.

In a previous paper[2] the importance of these four factors has been discussed in considerable detail and general principles suggested for consideration in connection with each. In this article, consideration will be given to the application of these principles to the three painting problems involved in the maintenance of pipe line and storage structures.

Painting to Cut Evaporation Losses

In the early days of tank painting, protection against corrosion at minimum cost was the objective rated as predominantly important in the selection of material. Based upon this criterion of value, blacks and iron oxide reds were the best materials available at the time for final-coat painting. As the petroleum industry developed, however, the appearance of tank farms and terminal storage became of increasing importance in the selection of tank finishes, and aluminum came into general use. With the widespread use of aluminum paints for tanks came the realization that evaporation losses, due to variations in interior temperatures from day to night could be materially reduced by using paints of high reflectivity until now for many types of tankage service the factor of light reflection overshadows the importance of both corrosion resistance and appearance.

The most important factor in selecting materials is not initial light reflection but, rather, average light reflection during the useful life of the finish. Certain paints may lose reflective value on weathering due to dirt collection.

Even though light reflectivity is considered an item of major importance in the selection of a tank coating, the factors of annual maintenance cost and length of protective life are, nevertheless, still important considerations. As the tank whites are designed to disintegrate by gradual surface erosion, their protective life and, therefore, their cost on an annual basis will be determined to a considerable extent by the rate at which they lose film thickness due to erosion. Strangely enough, self-cleaning and retention of light reflectivity are not

[1] Job, R., *Proc. Am. Soc. Testing Materials*, 93, 871-7 (1930).
Fifth Report of the Corrosion Committee (Iron and Steel Institute Special Report No. 21) pp. 9, 57-61, 305-6, 1938.
Speller, F. N., *Ind. Eng. Chem.*, 30, 1152-6 (1938).
Evans, U. R., *J. Soc. Chem. Ind.* 55, 337-41 T (1936).
Kappler, F., *Zeit Ver Dent, Ing.* 80, 183-5 (1936).

[2] C. F. Rassweiler, "Protective Coatings," paper presented at Twentieth Annual Meeting, A.P.I., November, 1939.

directly proportional to rates of erosion.

When a company is considering a painting schedule for structures situated in a large area encompassing regions of wide climatic variations, it may even be necessary to select different materials for different areas, as the paint representing a proper balance for the hot, bright sunlit area of Texas might chalk so slowly in the northeast as to be entirely unsatisfactory in self-cleaning. It is, of course, important that any tank white be resistant to sulphide-gas discoloration.

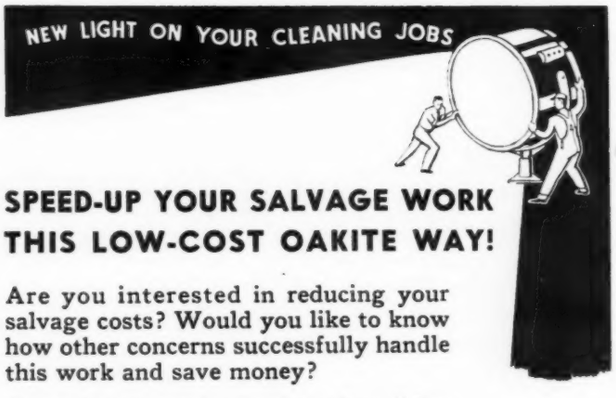
Proper preparation of the surface by adequate metal cleaning and careful selection of the primer reduces long-time maintenance costs in any tank painting program. This is particularly true, however, in maintaining white tanks. The white topcoat is designed to undergo gradual surface erosion; to obtain maximum value from the white topcoat, repainting should not be necessary or scheduled until the paint has chalked thin enough in appreciable areas to affect light reflectivity or appearance. Although properly selected tank whites will give very reasonable maintenance costs when applied over casual primer systems, the lowest maintenance costs will be obtained by selecting primers that not only have good inhibitive effect while protected by topcoats, but also have good durability when the eroding topcoat exposes areas of primer to direct sunlight. As in the case of ordinary tank painting, careful cleaning of the metal surface before priming lengthens the time between repaintings by decreasing the amount of corrosion under the still intact paint film.

No special precautions are necessary in the application of tank whites, except in connection with the application of full even coats of adequate film thickness. The white coat gradually loses film thickness on exposure until the film is too thin to hide the primer; repainting is then necessary to maintain reflectivity and prevent corrosion. Best results are, therefore, obtained by applying plenty of paint initially, thus making repainting necessary only at long intervals.

Finishing Problems Involving More Than Normal Exposure to Water and Chemicals

Probably no finishing problems require more careful analysis than do those involving more than normal exposure to water and chemicals. This is due partly to the fact that the conditions of exposure vary widely, ranging all the way from occasional wetting by wind-driven spray from adjacent cooling towers, to complete submergence. Also, the chemicals involved may vary from the relatively innocuous neutral salts in good drinking water, through the variations in alkaline spray waters, to actually strong acid and alkaline solutions. No one paint material is best fitted to meet all these requirements.

Where the finishing problem is sufficiently important to justify the use of quality materials, there are four types of products that ordinarily must be considered. These are the bituminous coatings, the alkyds, the phenol formaldehydes, and the chlorinated rubbers. In each class there are, of course, a wide variety of different products, but in this discussion reference will be made only to the more suitable in each group. In the case of the bituminous coatings this means materials whose properties are those of the bitumen and not of modifying oils; in the case of alkyds, rosin-free products specially designed for outside durability; in the case of phenol formaldehydes, those made from short-oil varnishes containing only pure phenolic gum, and, in the case of the chlorinated rubbers, products either oil-free or containing so little oil that the natural chemical resistance of chlori-



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nated rubber is not appreciably affected. Each of these materials has certain outstanding properties and certain deficiencies, as well.

The bituminous coatings, for example, have outstanding resistance to water and chemicals but become brittle on exposure to light and air and, in general, have poor durability where normal weathering is a material factor in film failure. In addition, they are most effective when applied in thick, hot coatings but such coatings have poor appearance.

The alkyd finishes have the best balance of properties where normal weathering is an important factor in film disintegration and exposure to water is intermittent and strong chemicals are absent. They are the least satisfactory for water immersion or where the chemical concentration is high enough to promote saponification. Their costs are intermediate between the inexpensive bituminous coatings and the more expensive phenolic finishes.

The phenolics have outstanding resistance to water softening or disintegration due to long contact with water or with mild chemical solutions, particularly mild acids. They are not resistant to strong alkali. Their most effective use is in cases where the finish is totally submerged or subjected to so much water spray or condensation that the destructive effect of the water or chemicals affects ultimate durability more than normal weathering.

The chlorinated rubber finishes are the most chemically resistant of the four, being quite inert to either water or relatively strong acids and alkalis. They are, however, the most expensive per unit of film thickness and the most difficult to apply in adequate film thicknesses, due to their high viscosity and poor application properties. In a moist atmosphere the chlorinated rubber finishes are of questionable value at temperatures above 150° F. Their maximum usefulness is in those instances where the acid or alkali concentration is too high to permit the successful use of phenolic-type materials.

It is easy to see how one material or the other may be most suitable, depending upon the relative importance of different properties for the particular use in mind. In general, most of the volume painting is done in areas where water contact is intermittent; for this purpose the alkyd finishes have been most generally used. For areas more constantly subjected to water, phenolic finishes have found extensive use. For places where appreciable concentrations of chemicals are involved, the chlorinated rubber products are being gradually adopted.

In selecting a material, attention must be given to the pigmentation as well as to the vehicle of the paint. Paints containing acid-sensitive pigments such as zinc oxide should not be used in acid areas and alkali-sensitive pigments such as iron blues, organic pigments, and aluminums should be avoided in alkaline areas.

Careful surface preparation before painting is of vital importance in areas subjected to water or chemicals. Any weakness in the metal-to-finish bond resulting from inadequate preparation of the surface before painting will result in quick blistering and early corrosion failure under conditions of severe water exposure. In addition, at the time of repainting, the areas exposed to chemicals or water are likely to present difficult cleaning problems and the tendency, unfortunately, is to consider a really thorough cleaning of the surface as being impractical. Unless rust and chemicals are thoroughly removed from these areas, however, the paint job should be recognized as only a mere "slick up" for appearance with relatively little value in preventing actual corrosion. The importance of this surface preparation was forcefully il-

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lustrated in a large chemical plant in which the management became so disturbed over the corrosion of the steel structures in the plant that they authorized the engineering department to conduct a thorough search for the most chemically resistant systems possible. During this search the erratic behavior of finishes that were in themselves extremely chemical-resistant led the engineers to make a study of the preliminary cleaning of the area to be painted. At the end of a four-year study they found in many areas that by adhering to the improved cleaning process that had been developed, they were able to return to the relatively inexpensive materials originally abandoned, and still get very satisfactory protection.

Particular attention must be given to the question of application in connection with the finishing of areas subjected to water and chemicals. These areas are likely to be badly roughened by previous corrosion and special care must be taken to see that an adequate thickness of paint is piled-up over the rough sections. Also, considerable thought and ingenuity is frequently necessary in figuring out methods by which the surfaces involved can be kept clean and free from water and chemical spray during the period between cleaning and priming and between the applications of subsequent coats. The application of either primer or topcoats over chemical deposits will lead to early failure. Finally, care must be taken to see that the finish has adequate time to dry and harden before it is again subjected to the action of water or chemicals.

Because the resistance of a paint film to passage of water is directly proportional to its film thickness, it is obvious that the application of an adequate paint thickness is particularly important in places subjected to severe water exposure. In general, it is better to build up this adequate film thickness by successive fairly thin coats rather than by one or two very heavy coats. This gives maximum hardness throughout the films, rather than a hard surface and a soft underpart that is relatively water-sensitive.

Painting of Galvanized Iron

Where long-time use is intended there is a growing realization that zinc coating of metal is not a substitute for painting but rather that a zinc and a paint coating combined give durability and corrosive protection that cannot be achieved with either alone. The zinc coating needs paint protection to prevent its disintegrating as the result of the action of water and air, or acidic industrial gases, and the paint coating will last a lot longer if it has an undercoating of zinc to help prevent rusting in thin spots and scratches.

Painting of galvanized metal, however, is obviously useless unless materials are selected that will adhere permanently to the zinc surface. Fortunately, primers of this type are now available. These primers contain zinc dust and it is apparently important that this zinc dust be incorporated in a specially designed vehicle. Dr. H. J. Wing[3] has shown that when paint is applied over zinc, water-soluble soaps are formed at the zinc-paint interface due to the reaction of the acidic decomposition products of the paint with the zinc. These water-soluble soaps aided by moisture coming through the paint film, destroy adhesion of the paint coatings so that strains induced by temperature changes cause the paint to crack and peel. The zinc dust in the primers presumably causes these zinc soaps to form in the primer itself rather than between the primer and the metal, so that adhesion is not affected. Zinc-dust oil-type primers have been used for many years but much more satisfactory results have been obtained since zinc dust has been incorporated in specially designed vehicles. Such primers have now been in practical use for about nine years and have been giving very satisfactory and uniform results.

A great mass of work has been done on methods of preparing galvanized metal surfaces so that they would have good paint-holding properties. Most of the early treatments were based on the theory that poor adhesion was due to the smoothness of the zinc surface and the treatments were, therefore, designed to etch the surface or to impart thin deposits of copper. Actually the etching effect had little or no value and too frequently the treating materials were not thoroughly washed from the galvanized metal before painting; the water-soluble salts remaining after the treatment only hastened the loss of adhesion.

Before modern galvanized metal primers and surface treatments were developed, it was generally considered good practice to let galvanized metal structures weather for a considerable time before painting. Sometimes this involved only a few months of weathering, but frequently the structures have been allowed to weather until actual rusting sets in before painting is undertaken. This is no longer considered good practice because (1) proper materials will adhere to new zinc surfaces and (2) as the zinc coating and paint together form an ideal means of preventing corrosion, it is not wise to permit the zinc coating to be destroyed before applying the paint.

Where weathered galvanized metal structures are to be repainted, however, the same cleaning precautions should be followed that are ordinarily specified for steel. All rust should be thoroughly cleaned from corroded areas and particular attention paid to cleaning pitted places. Areas where the zinc coating is still intact should be brushed free of dirt and any loosely adhering zinc oxide; if any salts are present as the result of the action of acidic atmospheric gases, they should be removed by thorough washing before painting. Weathered zinc surfaces should be primed with a specially designed zinc-dust primer to get the most satisfactory results. These primers have relatively good corrosion resistance on steel; the whole area, including the places where the zinc coating has been removed, can be primed with the same material.

Whereas reasonable care in application should be taken in painting over galvanized surfaces, care in application and in obtaining adequate film thickness are both less important in painting galvanized metal than in painting ordinary steel. Although a reasonable thickness of paint is necessary to protect the zinc coating, corrosion will not appear at thin spots as quickly as it does on uncoated steel. The film thickness selected for the topcoat can be determined better by considering the length of time that will elapse before the film erodes through and forces repainting for appearance, rather than from considerations of impermeability and actual prevention of corrosion of the undersurface.

General

Some of the factors affecting paint performance can be controlled by the paint manufacturer, but others can be controlled only by the paint user. The great strides made during the last ten years in improving the performance of maintenance paints have been, therefore, the result of the joint efforts of the paint producer and the paint user. Outstanding examples of this are supplied by the advances made in painting tanks to prevent evaporation losses, in painting areas subjected to unusual water and chemical attack, and in painting galvanized metal surfaces. In each case the paint manufacturer has contributed improved materials and the petroleum industry has contributed more intelligent selection and more careful use. The background of successful coöperation that has been built up during the last ten years by achievements of this sort should produce even greater advances in the performance of maintenance painting in the future.

[3] H. J. Wing, *Ind. Eng. Chem.* 28, 242-3 (1936).

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Determination of Minor Variations in Line Pressure or Volume of Crude Oil Being Pumped

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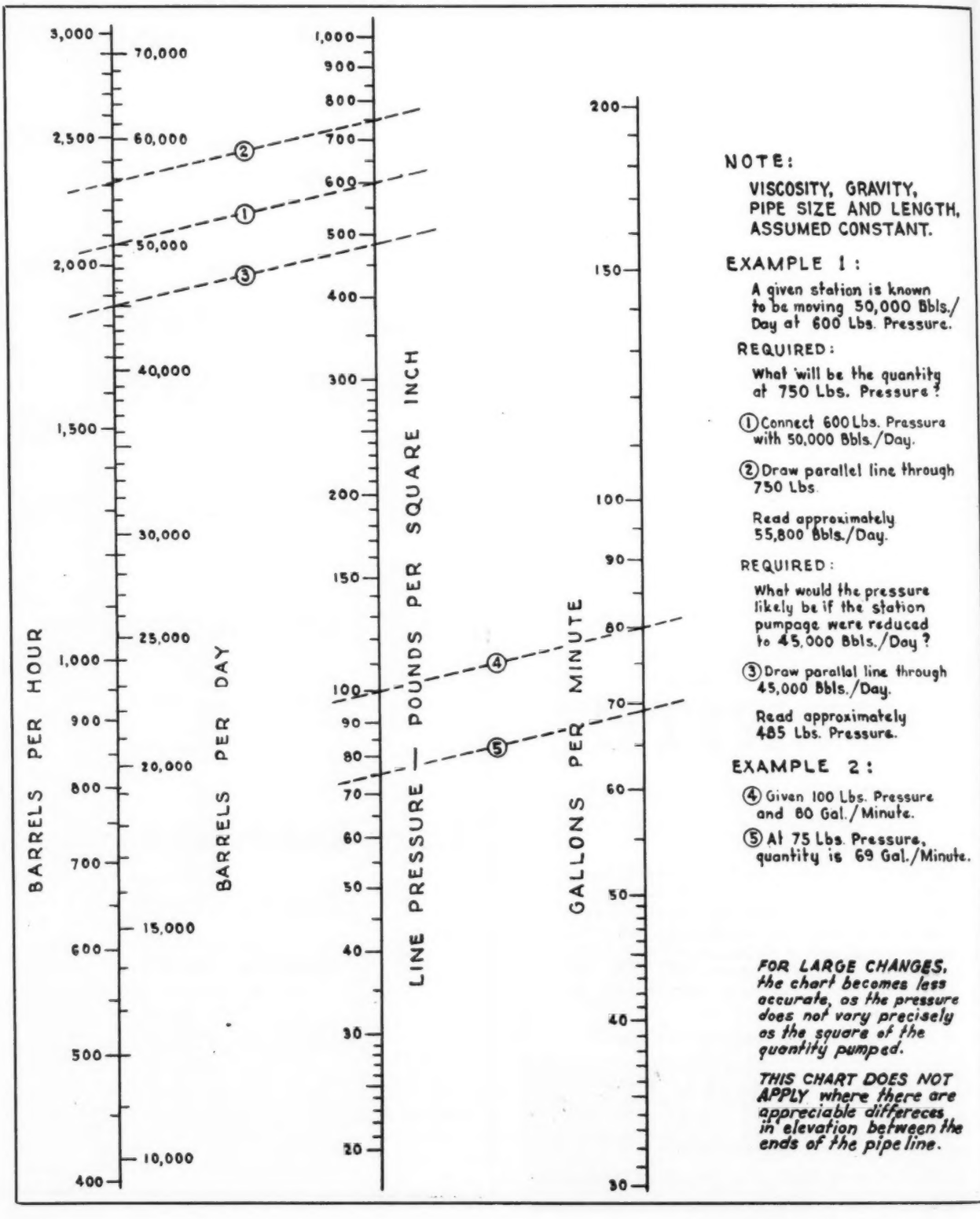
By FRANK E. HANGS



NOTE:

VISCOSITY, GRAVITY, PIPE SIZE AND LENGTH, ASSUMED CONSTANT.

EXAMPLE 1:

A given station is known to be moving 50,000 Bbls./Day at 600 Lbs. Pressure.

REQUIRED:

What will be the quantity at 750 Lbs. Pressure?

(1) Connect 600 Lbs. Pressure with 50,000 Bbls./Day.

(2) Draw parallel line through 750 Lbs.

Read approximately 55,800 Bbls./Day.

REQUIRED:

What would the pressure likely be if the station pumpage were reduced to 45,000 Bbls./Day?

(3) Draw parallel line through 45,000 Bbls./Day.

Read approximately 485 Lbs. Pressure.

EXAMPLE 2:

(4) Given 100 Lbs. Pressure and 80 Gal./Minute.

(5) At 75 Lbs. Pressure, quantity is 69 Gal./Minute.

FOR LARGE CHANGES, the chart becomes less accurate, as the pressure does not vary precisely as the square of the quantity pumped.

THIS CHART DOES NOT APPLY where there are appreciable differeces in elevation between the ends of the pipe line.

P 934.314
P 425.21

Layout and Care of Light Rotary Drilling Equipment

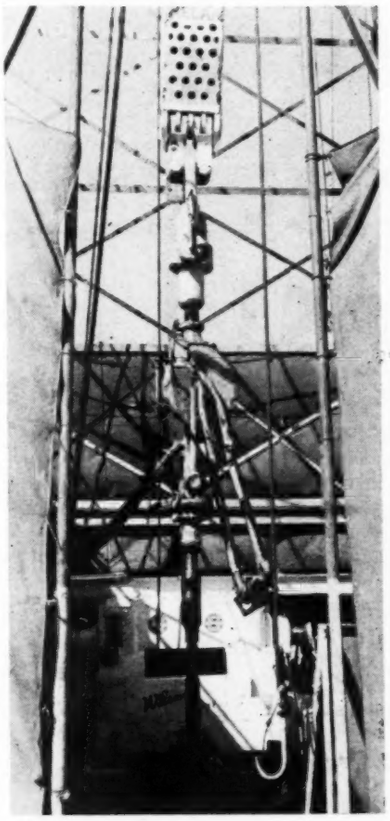
Factors that foster efficiency and safety in drilling operations

By H. LEE FLOOD
Associate Editor

OF THE many transitions occurring in the petroleum industry, day by day and year by year, sometimes so gradually that one is hardly conscious of the change, none is so remarkable as the advance that has been made in the general appearance and layout of equipment in the field. It is a source of pride to those deeply interested in the oil business to note on every side the desire to dress-up equipment and property and thus present a clean appearance to the outside world. One need only recall the usual unsightly oil-field or refinery scene of 15 or 20 years ago, to realize the progress that has been made.

As one example, accompanying the trend toward a more universal use of paint in all departments of the industry has been the change in the reasons for applying paint. There was a time when improved appearance was the only reason paint was used, so that justification for the expense was usually so intangible that often it was considered sheer extravagance. Although appearance still is an important factor, paint is now recognized more and more widely as an economic investment that definitely pays dividends to its user. Protection against rust and corrosion is perhaps recognized by more users as the outstanding benefit derived from paint. Other intangible benefits are becoming better known and more susceptible of evaluation as time goes on. For example, it has been pointed out that interior paints of the proper type speed up the output of office workers, lessen fatigue and nervousness, and otherwise contribute to the welfare of the workers and to the prosperity of the company adopting the practice. More to the point, operators in the oil fields, refineries, and various types of plants and stations found in the petroleum industry are recognizing similar advantages in the proper selection of paints to enhance the usefulness of their equipment.

At first glance startling because of its unique appearance and because of the distinct innovation from usual practice is the drilling equipment that has been made the subject of the present discussion. Virtually every piece of equipment included in the assembly has been painted with white enamel to obtain a perfectly smooth surface. The accompanying photographs have been selected as a means of conveying to the reader the pleasing appearance that is presented by equipment painted in this manner. Resembling more the appearance of a sanitary kitchen, it is difficult to realize that underneath the coat of white paint is an efficient, work-producing rotary drilling machine.



Canvas windbreaks frame the white-enameled traveling block and drawworks

Perhaps the first thought occurring to a practical man viewing the equipment for the first time is that it must be costly indeed to maintain equipment painted in such a manner. Louis Sikes, of Wichita Falls, Texas, owner of the equipment and sponsor of the all-white idea, insists that appearance is only one of the benefits he has gained by adopting this unique color scheme. Contrary to the belief that maintenance is more difficult, it is actually easier to keep the equipment clean for the simple reason that dirt and grease are immediately discernible to even the most casual observer. Important also, as it should be to every shrewd operator, is the pleasure and interest taken by his men in working with equipment that so rightfully occasions their pride. Important from the safety standpoint, too, is the ease with which the equipment may be seen at night by the members of the drilling crew.

Instead of scouting the idea of painting drilling equipment in this manner as an impractical one, it is believed that there is food for sober thought and serious study in the practice of using a light color, if not white, in painting equipment of this type. Certainly paint of the right quality will serve as a protective coating regardless of its color. Objection to its use then must rest rather pointedly in the care and labor of maintaining the spotless appearance that is mandatory against such a revealing background. In most instances the necessary attention would require little if any added expense—only added interest on the part of the workmen in employing their spare moments in clean-up work—work that is usually accepted and expected as part of the job but which often is shirked as much as possible.

Drilling Equipment

Equipment that presents a pleasing appearance certainly merits attention in regard to its layout. It is a rather obvious line of reasoning to assume that an operator who exercises attention to detail as evidenced in the selection of paint might also be appreciative of mechanical features and layout of the equipment. This assumption is strengthened by an inspection of the equipment in use.

It is apparent that thought has been given in every detail of the layout to

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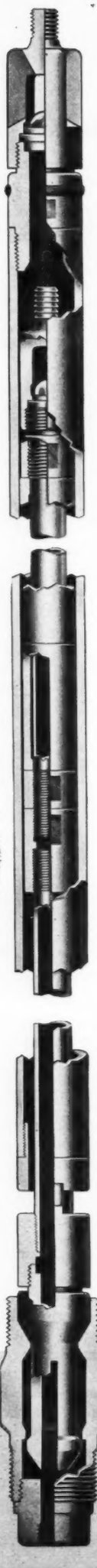

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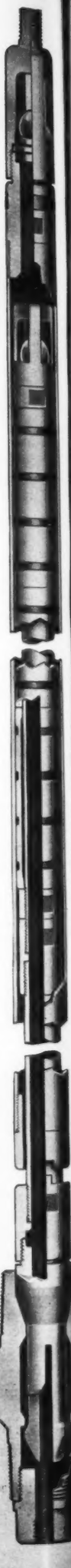
(RIGHT)

★ *Fast* to install, *easy* to pull, *simple* in construction—but hard to beat on *tough* well conditions...that's the "Volume Producer"! It meets every pumping requirement of both medium and large volume wells. Like all Flupaco Groove Seal Pumps, the "Volume Producer" has the largest cross-sectional displacement area possible in insert construction. It is made for either top or bottom anchoring in both traveling *plunger* and traveling *barrel* types for any desired method of installation.

★ The "Volume Producer" features sleeves of either "Supreme" or "Service" alloy steel, durable under all types of operating conditions. 9, 12 and 16 foot pump lengths and three diameters, with either single or double valves, provide a wide selection to meet all installation and pumping requirements.



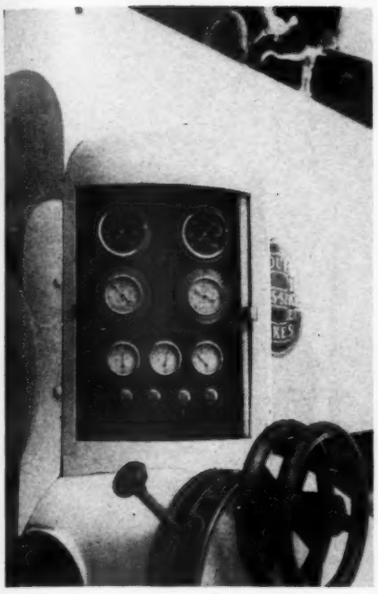
FLUID PACKED PUMP CO.

POST OFFICE BOX 64, LOS NIETOS, CALIFORNIA, U. S. A.

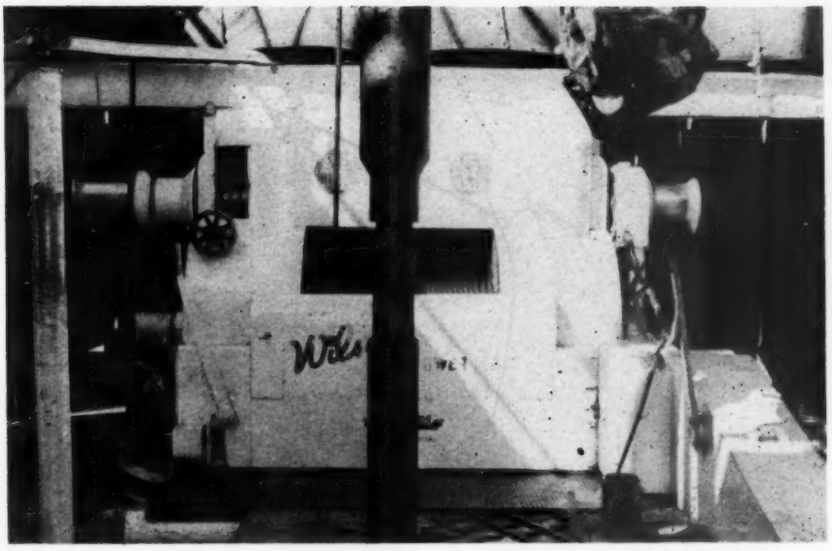
Mid-Continent and Texas Distribution

MID-CONTINENT: FLUID PACKED PUMP CO., 2 S.E. 29th St., Oklahoma City, Okla.

GULF COAST HEADQUARTERS: 2301 Congress Ave., Houston, Texas



Instrument panel and controls at driller's stand



An impressive appearance of neatness and efficiency is presented by the white-enameled equipment

facilitate operations as much as possible. Nearly every feature contributes in some way either to promote greater efficiency or to provide maximum safety to the workmen.

The drawworks installed is one of the latest designs of streamlined equipment on the market. All moving parts are totally enclosed in a heavy steel case so that there is little danger of injury to the crew. Mounted on a heavy steel frame, the transmission and drawworks are assembled as one unit, permitting a compact space-saving arrangement.

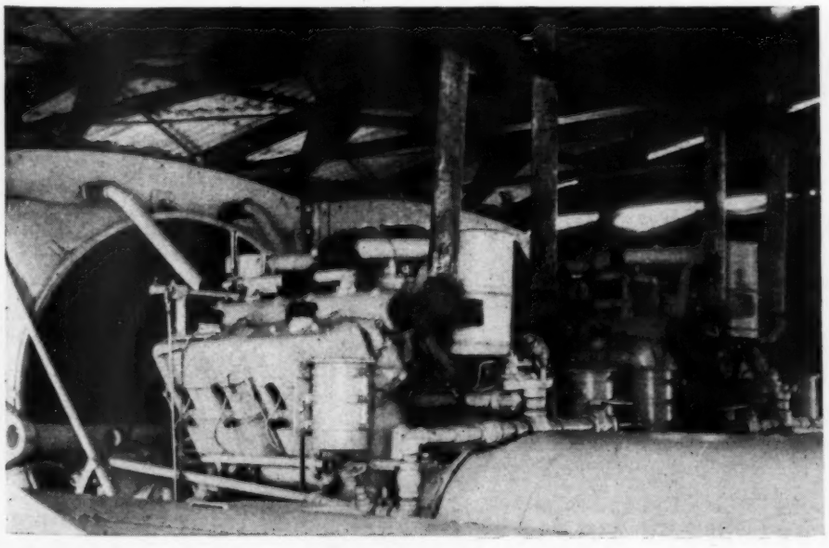
Two 225-hp. internal-combustion engines supply the power required by the drawworks and mud pumps. These engines are equipped to burn natural gas, gasoline, or butane as fuel. In drilling the well pictured in the photographs, natural gas from a nearby well is being used as fuel.

While at the rig, there was opportunity to observe the ease with which the driller and his crew manipulated the equipment in adding a joint of pipe. The drum clutches are air controlled through a valve placed conveniently at the driller's stand. Including this valve there are only nine controls required to operate the machine, all placed in a convenient control arrangement. There are two hand levers, one for the brake and one for the rotary table clutch. Two throttle wheels, just below the instrument panel, provide separate control of each engine. Speed of the drum is controlled by the lever placed just behind the throttle wheels. Two foot pedals serve as master clutch controls and another pedal automatically starts and stops the cathead.

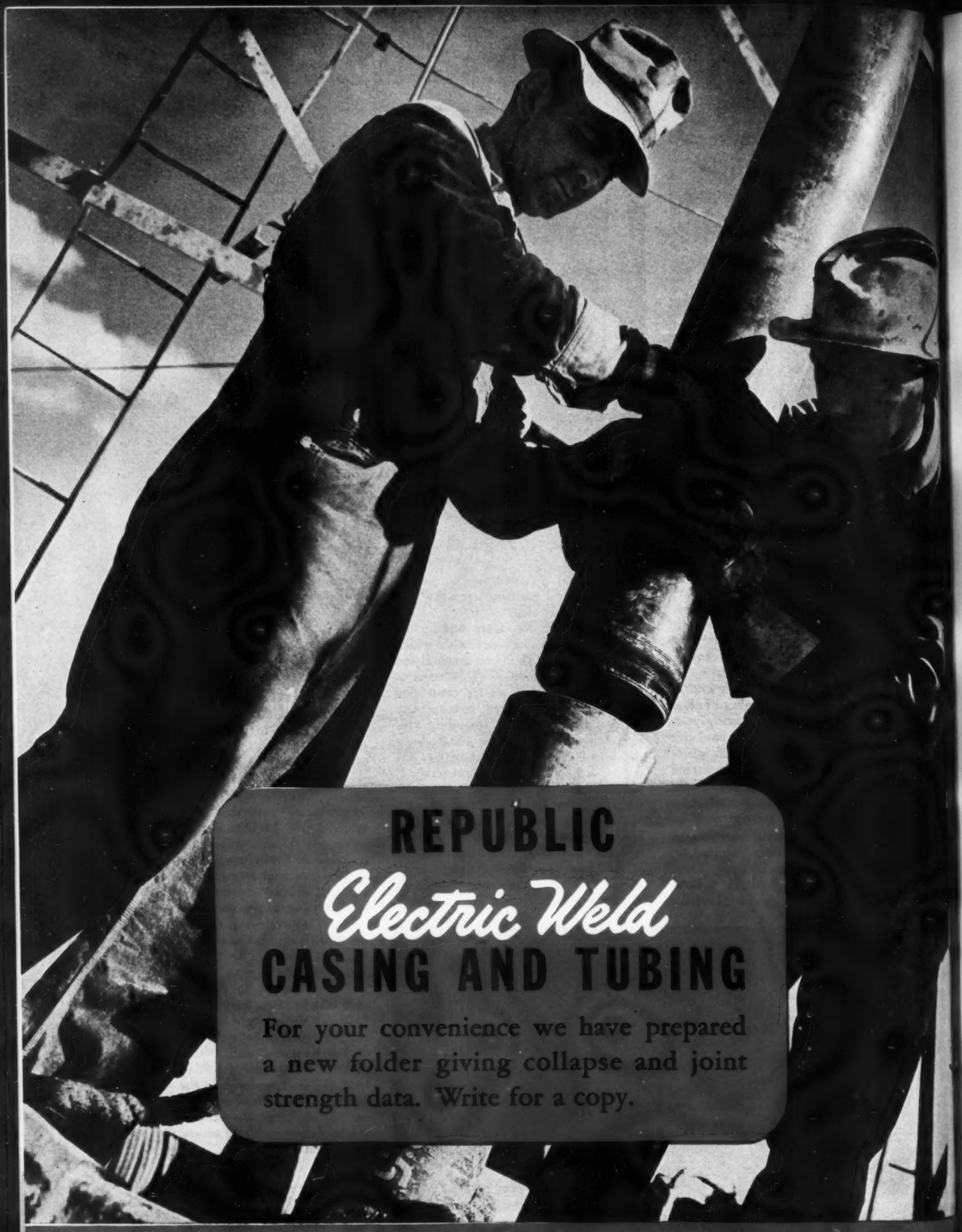
The 23-in. rotary table used with the rig is one of the latest type, rotating on 4-in. ball bearings completely enclosed and lubricated from only one point.

Sikes is a keen student of equipment, being appreciative of good service and quick to praise or condemn equipment on its merits. Indicative of his use of modern, improved equipment are the rotary bits now adopted as standard by Sikes. They are of an improved "streamlined" type that has only been available for a short time and their value over the older type formerly used is indicated by the comparative service —three bits were formerly used to drill 1000 ft. of hole, now only one is used.

Two identical rigs are being operated by Sikes in developing the extension of the K.M.A. field known as the Sikes field, in which the first well was drilled-in by the man for whom the field was named, in February, 1939. One of the rigs purchased in June, 1939, has drilled eight wells; the newer rig, purchased in January, 1940, is now drilling its second well. Wells are completed in either the 4000-ft. sand or the 4400-ft. sand underlying the area. A uniform 9.5-lb. mud is used throughout the drilling. No unusual drilling or completion problems are encountered in the field.



Even the 225-hp. engines are enameled white and maintained in spotless condition


REPUBLIC
Electric Weld
CASING AND TUBING
For your convenience we have prepared a new folder giving collapse and joint strength data. Write for a copy.

REPUBLIC STEEL CORPORATION

General Offices • Cleveland, Ohio

REPUBLIC STEEL

Berger Manufacturing Division
Niles Steel Products Division
Steel and Tubes Division
Union Drawn Steel Division
Truscon Steel Company

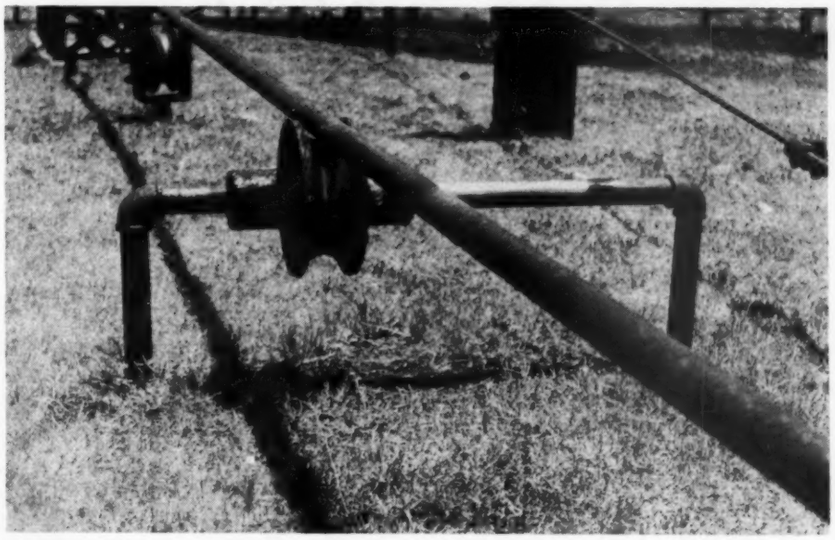
Reducing Rod-Line Friction

By
CHAS. C. LYNDE

MOUNTING one roller on a babbitted sleeve and the other in a swiveled yoke, one producer provides for lateral motion of the link from power to rod line with a minimum of friction.

When pumping the well, the joint at the knock-off takes the pivotal wear, with the roller nearer the power supporting a portion of the link weight. This roller, mounted on a sleeve filled with babbitt to slide on the 1½-in. pipe support, reverses readily with rod motion, and slides freely across its polished support, needing only infrequent lubrication to keep it running smoothly.

To take this well off production, the knock-off mechanism is actuated, permitting the outer end of the connecting rod to drop into the farther roller. This bearer is supported on a yoke, carried in a pipe standard, so that the roller or pulley can turn around a center to provide direct rolling of the rod from all points in the power operating cycle. When thus supported on the outer roller, the center of the connector is carried on the nearer pulley, which works freely to and fro on its slide to carry the rod without bending or lateral distortion.



Swiveled roller in background and sliding roller in foreground minimize friction and reduce lateral bending of rods

Program Eastern District Meeting A.P.I.

THE preliminary program of the spring meeting of the Eastern District, Division of Production, American Petroleum Institute, to be held at the Deshler-Wallick Hotel, Columbus, Ohio, April 11 and 12, has been announced as follows:

Thursday Morning, April 11, 1940

8:30 A. M. Registration, Deshler-Wallick Hotel, Columbus, Ohio. Registration headquarters will be open at 3:00 P. M., April 10. Registration fee $1.50.

10:00 A. M. Morning session. Presiding: Dewitt T. Ring, The Preston Oil Company, Columbus, Ohio.

1. Address of Welcome—Hon. John W. Bricker, Governor of Ohio.
2. "Conservation and Proration Without Allowables," by Roger C. Hutchings, American Petroleum Institute, New York, New York.
3. "Water Treatment for Prevention of Scale and Corrosion in Connection With Water Flooding," by F. T. Redman and R. F. Mackie, Hall Laboratories, Pittsburgh, Pennsylvania.

Thursday Afternoon, April 11, 1940

2:00 P. M. Presiding: J. J. Schmidt, The East Ohio Gas Company, Cleveland, Ohio.

1. "Lubrication of Oil Field Equipment," by A. L. Foster, Lubri-Zol Corporation, Cleveland, Ohio.
2. "Review of New Developments, Procedures and Methods in Drilling and Completing Wells," by E. A. Shakley, Exploitation Engineer, Shell Oil Company, Inc., Centralia, Illinois.
3. "Appraisal of Oil Properties," Ralph E. Davis, Ralph E. Davis, Inc., Pittsburgh, Pennsylvania.
4. "Portable Compressors," by J. A. Thompson, Belmont Quadrangle Drilling Corporation, Bradford, Pennsylvania.

Thursday Evening, April 11, 1940

7:00 P. M. Annual dinner and entertainment—Deshler-Wallick Hotel.

Friday Morning, April 12, 1940

9:30 A. M. Presiding: M. G. Gulley, Gulf Oil Corporation, Pittsburgh, Pennsylvania.

1. "Problems in Deep Cable Tool Drilling, Appalachian District," by J. A. Fox, Foley and Fox, Washington, Pennsylvania.
2. "Crude Oil and Its Competitive Fuels," by Dr. Gustav Egloff, Director of Research, Universal Oil Products Company, Chicago, Illinois.
3. "Electric Logging," by J. D. Gustafson, The Carter Oil Company, Dix, Illinois.
4. "Interesting Developments in Michigan," by George Myers, Sun Oil Company, Toledo, Ohio.

Friday Afternoon, April 12, 1940

2:00 P. M. Presiding: W. A. Watkins, The Carter Oil Company, Mattoon, Illinois.

1. Business meeting—Election of officers.
2. "Multi-Sand Completions," Bart DeLaat, The Pure Oil Company, Olney, Illinois.
3. "Geology and Development of the Illinois Basin Area," Dr. A. H. Bell, Geologist and Head of Oil and Gas Division of the State Geological Survey, Urbana, Illinois.
4. "Use of A. P. I. Tubular Goods—Appalachian District," J. B. Graham, National Tube Company, Pittsburgh, Pennsylvania.

BAKER CEMENT RETAINER

CASE STUDY NO. 402

A Case study of an Actual Well Completion Problem Solved By Using the Baker Cement Retainer

Problem: To shut off water entering from bottom of producing zone.

Method: Squeeze cement with Baker Cement Retainer equipped with 50' (drillable) Tail Pipe.

Result: Water completely shut off (before performing squeeze, production was cutting 35% water).

• DETAILS •

Field: Kilgore, Texas

Depth of Well: 3700'

Depth Retainer Set: 3630'

Breakdown Pressure: 500 #

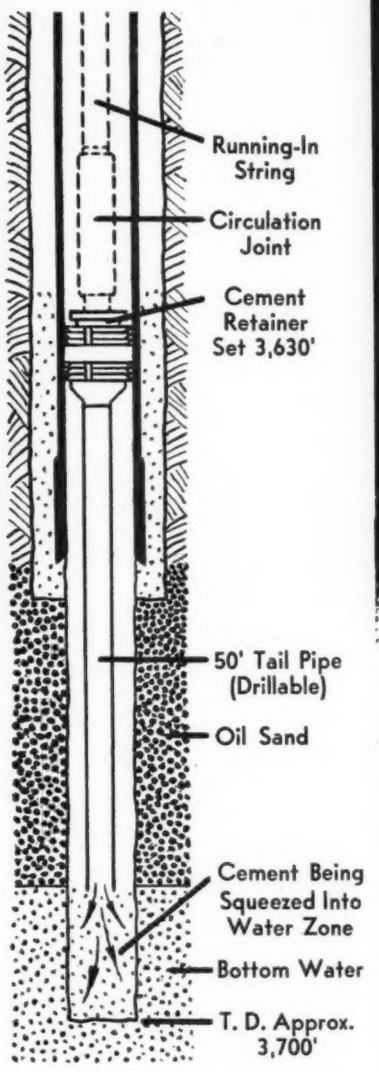
Final Pressure: 2100 #

Number of Sax Put Away: 534

How Cement Discharged: through lower end of Tail Pipe into open hole.

BAKER CEMENT RETAINER — SAVE A WELL

"For Friendly Service, and Dependable Products, Specify BAKER."



Squeeze cementing with Baker Cement Retainer (with Tail Pipe) to shut off bottom water.

IF YOU HAVE water problems the Baker Cement Retainer may provide a safe, economical solution to these difficulties. Complete details concerning the Baker Cement Retainer and its many important field applications will be found in the Baker section of the Composite Catalog; also in the Baker Broadcast No. 17-A. The latter is a comprehensive, 40-page illustrated treatise which will be sent to any interested oil man upon request.

BAKER OIL TOOLS, INC.

P. O. Box 127, Vernon Station, LOS ANGELES, CALIFORNIA
P. O. Box 3048, Houston, Texas • 19 Rector St., New York City

IMPORTANT BAKER CEMENT RETAINER APPLICATIONS INCLUDE: Squeeze Jobs Re-Cementing • Cementing Behind Sections of Pipe • Reducing Gas/Oil Ratios • Series Cementing Plugging Off Bottom Fluids • Plugging Back to Upper Zones • Testing Upper Cased Formations As a Heaving Plug • As a Bridge Plug at any Place in Casing or Liner

BAKER CEMENT RETAINER

NEW INFERNO BLUE FLAME LOW PRESSURE GAS BURNER

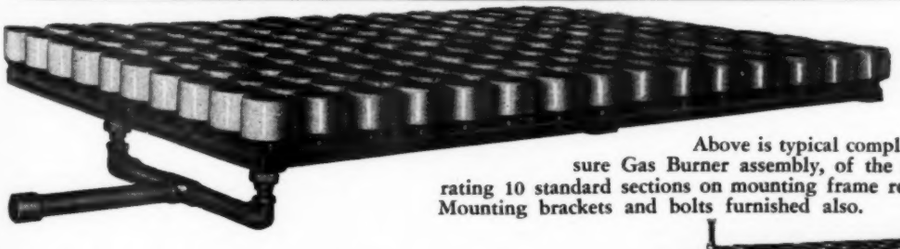
CROSS SECTION OF NEW DOUBLE-REVERSING BURNER CUP

Gives 10% More Boiler H. P.... Saves Fuel & Boiler Repairs

A STANDARD UNIT 15-CUP BURNER SECTION

We believe that the new INFERNO Blue Flame Low Pressure Gas Burner of improved design is the best burner ever offered the oil and gas industry. We urge contractors and operators who are interested in increasing efficiency... reducing fuel and repair costs... to check the following features:

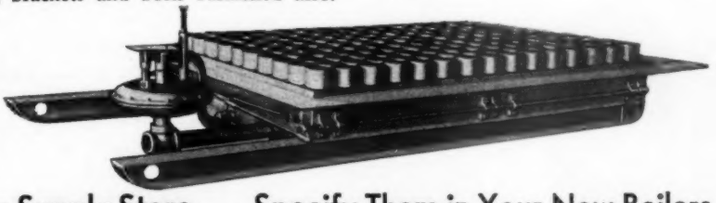
- ★ By scientifically designing the burner cup to thoroughly mix the air and gas by double-reversing, a low blue flame is developed with intense heat close to the burner.
- ★ 10% more h. p. is gained.
- ★ Tests with this new burner reveal from 10% to 11% CO_2, a percentage much higher than competitive burners.
- ★ Operates perfectly on gas pressures ranging from 4 oz. to 10 lbs.
- ★ Entire burner assembly made of special heat-resisting metal, withstanding temperatures as high as 1550 degrees F., without growing or expanding.
- ★ Furnished with proper orifice size for efficient combustion of any specific gas from natural to butane.
- ★ Entire burner assembly is permanently fastened in boiler to eliminate loss and breakage in moving.
- ★ Burner insert screw-locks in burner cup, and burner cup screw-locks in frame—making the burner assembly one complete unit.
- ★ Manifold is eliminated by incorporating manifold facilities in the double-duty frame of each section.
- ★ Each section, 15" by 25" and only 7" high, contains 15 burner cups. Threaded outlets on all four sides. Can be easily arranged in groups to fit the fire box of ANY BOILER.
- ★ Entire burner unit shipped from the factory completely assembled and pre-tested, insuring quick and correct installation.



Write for
NEW BULLETIN No. 13-A

Above is typical complete INFERNO Blue Flame Low Pressure Gas Burner assembly, of the new and improved design, incorporating 10 standard sections on mounting frame ready for quick and easy installation. Mounting brackets and bolts furnished also.

At right: One of the New INFERNO Blue Flame Low Pressure Gas Burners equipped with the newly perfected INFERNO Automatic Damper Control. This installation gives proper control of secondary air by automatic shutter-door action along sides of the fire box.



Insist on Them at Your Supply Store . . . Specify Them in Your New Boilers

INFERNO

THE **INFERNO** CO.

"Makers of Better Steam Equipment"

P. O. BOX 1138 SHREVEPORT, LOUISIANA, U. S. A. 115 RICOU STREET

MACHINERY and EQUIPMENT

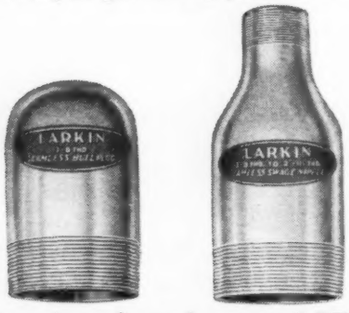
High-Pressure Lubricated Plug Cock for Gauge Lines

TO provide a leak-proof gauge cock that can be completely opened or closed with ¼ turn, engineers of Merco Nordstrom Valve Company have developed a lubricated type for test pressures to 4000 lb. This gauge cock has a rated working pressure for water, oil, and gas of 2000 lb. Its body is of forged steel and it has a stainless steel plug. Stick lubricant is inserted under a lubricant screw that can be turned down. Turning of the screw transmits hydraulic pressure to the seat, and in the event the cock becomes hard to turn, the pressure exerted will loosen it. Special lubricants are available for steam. This gauge cock is made in ¼ in. and ⅜ in. sizes and is wrench-operated. Details may be obtained from Merco Nordstrom Valve Company, 400 Lexington Avenue, Pittsburgh, Pennsylvania.

"Zin-Coting" by Larkin

THE Larkin Packer Company, St. Louis, Missouri, has announced the development of a new type of finish that is to be used as a coating on the company's complete line of swage nipples and bull plugs.

A product of Larkin's own laboratories, the new finish is described as a zinc coating that is deposited by an electrolytic galvanizing process. It has



been given the trade name of "Zin-Coting" and is said to prevent corrosion even under the worst conditions, thus assuring a perfectly free running thread.

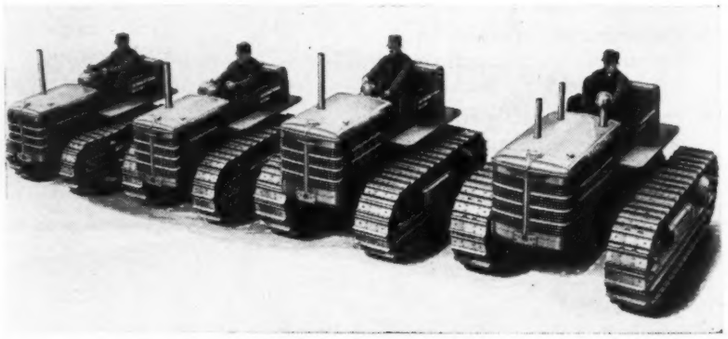
The Zin-Cote finish is a plate and not a paint and is designed to insure a bright surface for the life of the fitting. It will not peel off nor chip. The finish is produced in Larkin's own plant under close supervision and inspection, it is stated.

Larkin swage nipples are forged from new, seamless, full-weight pipe or casing and swaged to the proper size and shape by a bull-dozing machine to insure complete uniformity of product. The forging temperatures are carefully controlled in furnaces built especially for swage nipples. The inside edges of the nipples are chamfered to eliminate all sharp corners and burrs that might cause bad cuts, threads are perfectly turned out, and the ends of the nipples are faced square and beveled to assure quick and easy starting.

Larkin bull plugs, on which the new finish is also used, are pressed from flat plates of deep drawing stock to insure a weldless as well as a seamless plug. The forging and machining operation are accomplished with extreme accuracy, it is asserted. All plugs under 2-in. are machined from cold rolled bar stock. Larkin pioneered the hexagonal feature in bull plugs and it is now practically a standard feature of their smaller sizes, the manufacturer states. The shape permits the use of an adjustable or open wrench of any type.

Company officials announce that, in recent tests, bull plugs in the 2-in. size withstood 10,000-lb. pressure without apparent distortion. Ten-inch plugs withstood a pressure of 2,600 lb. per sq. in. under similar test conditions.

International Diesel Crawler Tractors



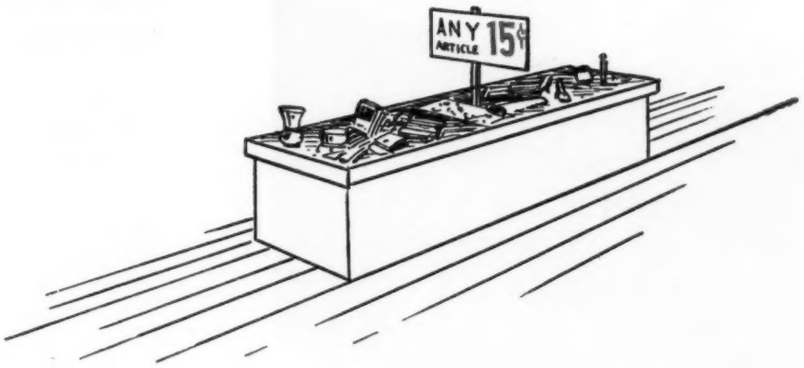
A YEAR ago the International Harvester Company, Chicago, Illinois, announced the Model TD-18 Diesel TracTracTor. It was and still is the largest in the International crawler tractor line. Now, three new similarly styled and engineered International Diesel crawlers have been announced. They are the TD-6 TracTracTor, smallest of the three new models; the TD-9, next in size, and the TD-14, largest of the three.

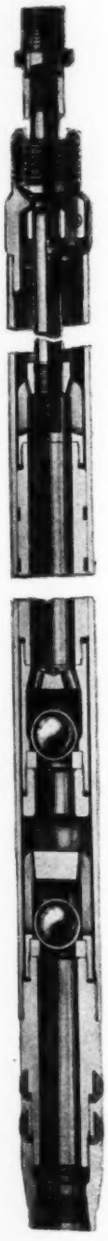
Thus, with the larger TD-18, previously announced, the International Diesel crawler line now consists of four sizes, with drawbar horsepower ranging from 30 for the TD-6 to more than 70 for the TD-18. A TracTracTor of same size as the TD-6 and to be known as the T-6 will be available soon with a combination gasoline-distillate engine.

Every one of these new TracTracTors is equipped with a full-Diesel engine giving full-Diesel fuel economy. As has been the case with other International Diesels, each engine of this new line is provided with a distinctive method of starting by which it starts on gasoline and, after about a minute of operation, shifts to full-Diesel operation. A conventional automotive-type electric starter is regular on the TD-18 and is available as special equipment for each of the other models.

The engine of the TD-18 has six cylinders and the engine of each of three smaller models four cylinders, all being of the 4-cycle, full-Diesel type.

Quality is NEVER on the Bargain Counter!





AXELSON

DEEP WELL PLUNGER PUMPS AND SUCKER RODS

A pump that is low in price is not necessarily *low in cost*. The same is true of sucker rods. Their real cost is determined by the length of service they render under the particular conditions encountered, their efficiency in operation, and freedom from the need for frequent repair and replacement. In short, the *proved quality* built into them by the manufacturer is the gauge by which you can anticipate the ultimate cost of a pump and string of sucker rods — and quality is NEVER found on the bargain counter.

Axelson builds plunger pumps and sucker rods to meet all known field conditions. Naturally, they vary in price, but their QUALITY is rigidly held to the high standards maintained by Axelson throughout 48 years of manufacturing plunger pumps and sucker rods.

AXELSON *Sure-Seal* PUMPS

Lower pumping cost and efficient operation of the Sure-Seal Pump are insured by three outstanding factors: (1) The barrel tube is made of cold-drawn precision seamless steel tubing with the bore honed to a mirror finish and to a definite diameter and close tolerances. (2) Plungers are chromium plated for hardness, friction reduction, and corrosion resistance. (3) The pin type construction of both ends of the plunger prevents them from being expanded when fittings are tightened, thus avoiding damage to the chromium plating and scoring of the barrel tubes.

AXELSON *59* SUCKER RODS

Made from a nickel-molybdenum alloy steel, fully normalized and drawn from end to end, after forging but before threading. This treatment results in the proper balance of chemical and physical properties and in an excellent combination of strength, ductility and shock resistance. These rods are recommended for wells where extra heavy loads are encountered and where irregularities in pumping movements are unavoidable. The alloy content in these rods aids materially in their resistance to corrosion fatigue.

THERE IS NO ECONOMICAL SUBSTITUTE FOR QUALITY

Axelson Manufacturing Co.

P. O. Box 98, Vernon Station, Los Angeles • St. Louis • 50 Church Street, New York • Tulsa • Mid-Continent and Eastern Distributor: Frick-Reid Supply Corp. • Rocky Mountain Distributor: Great Northern Tool & Supply Co.

AXELSON

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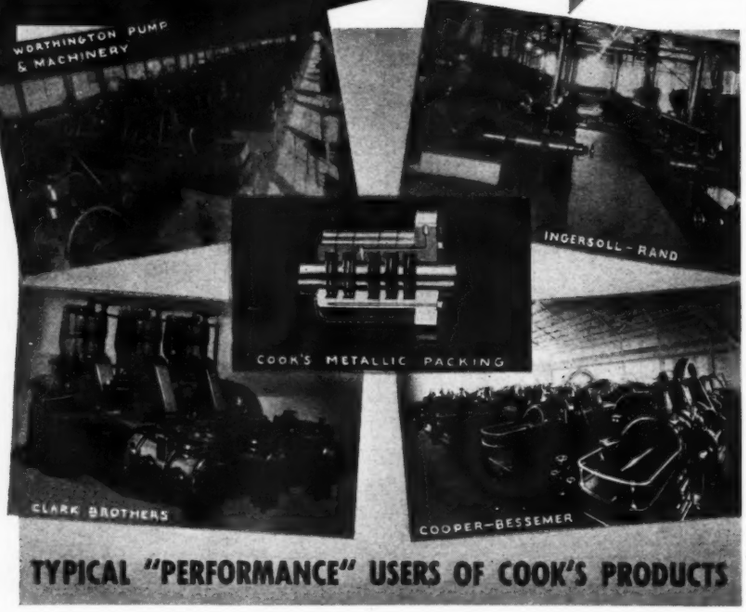
DEEP WELL PLUNGER PUMPS & SUCKER RODS

SEALING PRESSURES SINCE 1888

On the Gas Pipe Lines it's COOK'S METALLIC PACKINGS



TYPICAL "PERFORMANCE" USERS OF COOK'S PRODUCTS

Over 90% of Gas Engine Driven Compressors built in recent years are COOK-equipped

Only a **superior product** can win such overwhelming preference—and then only after demonstrating its superiority, over and over again, in widespread usage, under a wide range of service conditions.

For over 50 years COOK'S Metallic Packings have been proving their unequaled sealing efficiency, their extra long life, their friction reducing and rod preserving properties—in short, their ability to provide **maximum performance at minimum expense.** When you order new equipment, you want this trouble-and-money-saving packing—so make sure you get the genuine by **specifying "COOK'S Metallic Packing" by name.** For equipment in service, order from your engine builder or consult us direct.

And now read about COOK'S Piston Rings on the opposite page ➡

C. LEE COOK MANUFACTURING CO.
INCORPORATED
New York Cleveland Los Angeles Baltimore LOUISVILLE, KY. Chicago Tulsa New Orleans San Francisco

Method Developed For Squeezing Formation When Liner Is Set

A METHOD whereby the operator may squeeze the formation at the time the liner is set, eliminating the expense and time involved in an extra round trip, has been introduced to the oil industry by Brown Oil Tools, Inc., Houston, Texas.

The Brown Type "P" packer has been developed to run on the last joint of liner in conjunction with a Brown Type "T" or "V" set shoe. The packer is collapsed in the conventional manner after the liner is run to bottom.

One of the outstanding features of this new Brown packer is that, once set, it cannot move up the casing nor lose its seal, because it has ratchet slips on a buttress thread on the inside and hold-down slips on the outside.

Squeezing is accomplished by pumping through the set shoe and around the liner, squeeze pressure applied being equalized inside and outside the liner with no part of the liner subjected to stresses sufficient to cause bursting or collapse. Pressure is held in the liner by the use of inverted swab rubbers on the tail pipe of the setting tool. The assembly also permits the formation to be broken down with water very satisfactorily, according to the manufacturer, before the squeezing with cement is done. When squeeze pressure is released and the cementing string is picked-up, excess cement may be circulated from the hole, leaving the squeeze pressure on the formation until the cement sets.

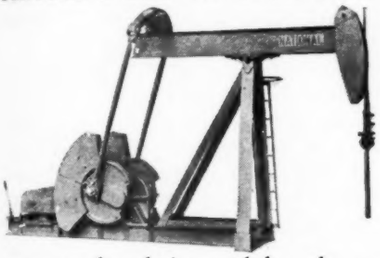
The Brown set shoe is built of special-alloy cast-iron that readily drills out.

It is asserted that this method permits the squeezing of the entire lengths of liner in the hole without the necessity of bridge plugging, squeezing, and drilling-out operations previously required to squeeze-off water sand prior to setting liner.

Full details of the method and the tools involved will be supplied by Brown Oil Tools, Inc.

National Unit Pumpers

THE National Supply Company, Toledo, Ohio, has recently added two new unit pumpers to its line. These units, known as the TU304-HD30TB and the TUS304-HD30TB, are designed for medium single well pumping service. The Type TU304-HD30TB is made for installation on



concrete foundation and has the reduction gear mounted directly on the frame. The Type TUS304-HD30TB has the same features and specifications as the Type TU304-HD30TB pumper except that a sub-base between the frame and reduction gear provides the necessary height for the counterweights to clear the bottom of the frame, so that installation may be made on derrick floors or on flat concrete pads.

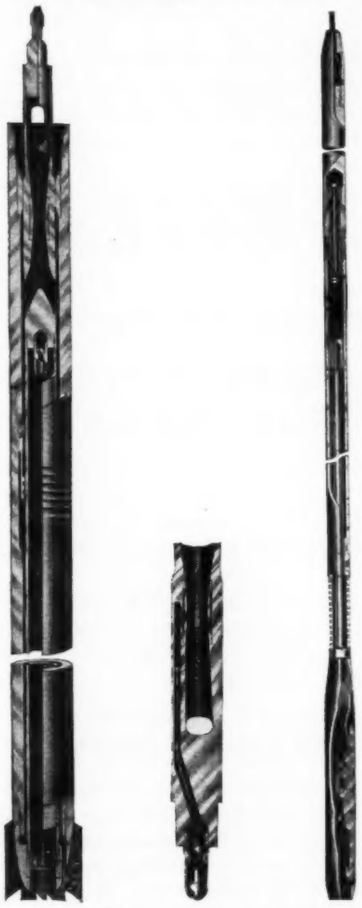
Both units have a maximum polished-rod stroke of 48 in. and the safe load of walking beam is 12,750 lb. A.P.I. The A.P.I. peak torque rating is 76,500 in-lb. at 20 s.p.m. and the overall gear ratio is 29.6. A fully equalized pitman assembly and roller bearing wristpin housings are regular equipment. National Type B eccentric cranks and counterweights give infinitely and continuously variable adjustability, both in counterweight effect and degree of lag and lead. The counterweights are of the one-piece type and are clamped in the desired position on the circular rim of the crank. Adjustment is by power with no lifting required. A complete description of these two units may be found in National's Bulletin No. 260.

BJ Elliott Wire-Line Core Drill

SINCE the recent acquisition of the Elliott Core Drill Company by Byron Jackson Company, Los Angeles, California, many improvements have been made in the design of the wire-line core drill introduced some time ago by the former company. The core drill, known as the BJ Elliott Wire Line Core Drill, is being constructed in units as follows:

1. The outer barrel is made of high-quality, heavy-drill-collar stock, wickered on the exterior for easier handling, and containing a packer ring and driver clutch. Bits for use on this drill collar include a 2-way, 3-way, and 4-way bit, all of the pilot type and hard-faced with tungsten carbide. Hard-faced roller type bits are supplied for shales and hard rock formations.

2. The retractable inner barrel (core-taking assembly) rests freely in the drill collar assembly and is held in position by pump pressure only. No driving mechanism or latching device of any description is used. The elimination of "hold-down" mechanisms avoids the possibility of mud and cuttings settling about the inner barrel and freezing it inside the outer barrel. This feature assures easy, positive recovery of the BJ Elliott wire-line core drill at all times, the maker asserts. The core drill takes full length, (10 to 12 ft.) uncontaminated cores with high percentage recoveries due largely to the operation of a patented inner barrel valve, it is stated. This venturi type valve performs two functions: (1) Pump pressure on top of the valve holds the inner barrel assembly on a shoulder in the bit; (2) The high velocity section of the valve is constructed to exert a suction at the upper end of the core-taking barrel, which bleeds off mud and cuttings and aids the entry of cores from loose and unconsolidated formations. Full length core-taking is also facilitated by eliminating the protruding bit, the manufacturer states.



The Rings that Excel in Material, Design, Workmanship and Performance . . .

COOK'S Piston Rings, like COOK'S Packings, are favored on pipe line equipment because they have proved their superiority on the job. In materials, design and workmanship they provide everything you can ask for in piston rings—everything needed to assure highest operating efficiency, long life to both rings and cylinders, and minimum upkeep costs. And because COOK'S Rings are made in all conventional types and many special designs, you can be sure of combinations that are correct for your specific engine and fuel conditions. Ask our engineers to recommend the ring combination that will give you best results.

Read about COOK'S Metallic Packing on the opposite page.

C. LEE COOK MFG. CO.
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LOUISVILLE, KY.
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Diesel Engine Added to Cooper-Bessemer Line

LATEST addition to the line of vertical Diesel engines manufactured by the Cooper-Bessemer Corporation, Mount Vernon, Ohio, is the Type JS. This new, 4-cycle Diesel incorporates all outstanding features of the makers' JT and JTB engines, adding further to their overall efficiency and economical operation while increasing horsepower, the manufacturer asserts.

The base of the Type JS Diesel engine is divided close to the centerline of the crankshaft, and the cylinder block is bolted to it by steel tie-bolts extending to a point just above the crankcase covers. Separate cylinder liners of the wet type are fitted with oil-proof grommets at their upper and lower ends to seal the water joints. These liners are held down and in place by the cylinder heads and are supported on shoulders a few inches below the tops of the liners.

The JS crankshaft is a one-piece steel forging having a diameter of 9 in. Main bearings in the engine are babbitt-lined steel shells of the precision type, with shim adjustment. The main bearing cap is set into the bedplate to hold the bearing firmly in place and provide accurate alignment.

Die-forged steel connecting rods are used, having two-piece crankpin boxes and fitted with fully removable precision bearings with shim adjustment. The piston pin ends of the connecting rods are bolted solid to the piston pins

to provide greater bearing surface. Piston pin bearings are two-piece solid bronze shells, which afford an almost full-length bearing. Undersides of Type JS piston crowns are jacketed and oil cooling is provided. This oil cooling of pistons is a new feature of "J" line engines and goes far toward eliminating wear, warpage, and sticking of piston rings, and scuffing of liners, at the same time assuring lower piston temperatures, which, in turn, permit higher speeds and greater horsepower output with no danger to piston assemblies, the makers state. Eight piston rings are used, five of the compression type and three of the oil control type, with one of the latter placed below the piston pin.

For stationary power and Diesel-electric generating service, the Type JS Diesel engine is offered in 5-, 6-, 7-, and 8-cylinder units rated conservatively at 430, 525, 600, and 675 hp., respectively, at 400 r.p.m. For direct-reversing marine applications, it is available in 6-, 7-, and 8-cylinder sizes, of 525, 600, and 675 hp. at 400 r.p.m. Cylinder bore is 13 in.; stroke 16 in.

Lincoln Announces Stainless Steel Electrode

A NEW stainless steel electrode known as "Stainweld D" is announced by The Lincoln Electric Company, Cleveland, Ohio. "Stainweld D" should be used for arc-welding stainless steel of the 25 percent chromium, 20 percent nickel type, such as Iron and Steel Institute No. 310, the manufacturer asserts.

"Stainweld D" is also used for welding various stainless steels to mild steel and for welding steels that are air hardened and cannot be treated after welding, such as armor plate and similar steels.

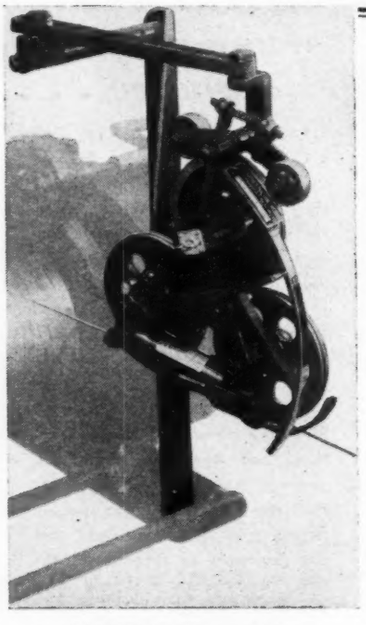
Directions for its use are as follows:

Hold arc length short as possible without choking or sticking.

In general, preparation of the work and welding procedure are similar to that used in mild steel welding. Surfaces to be welded should be free from all foreign material. Slag should be thoroughly cleaned. Thin sheets should be clamped against a copper backing to maintain alignment, reduce buckling, and prevent burning-through.

Emco Pilot Loading System of Pressure Regulation

IN THE operation of regulators for pressure control, there are many operating conditions that require a very high degree of sensitivity and control accuracy. Recent developments in distribution, measurement, and combustion service demand close control of operating pressures. In anticipation of these requirements, the Pittsburgh Equitable Meter Company has announced the Emco Pilot Loading Control System, perfected to provide operating characteristics that they state



MATHEY Measure Meter and Weight Indicator

MEASURE METER and WEIGHT INDICATOR

This new measuring device eliminates the factor of human error in well measuring operations, by indicating, on easily read dials, the weight and length of line in the hole.

The Type B Measure Meter and Weight Indicator is adaptable to all units using measure meters. It is built for any size measuring or torpedo line.

MATHEY PORTABLE MEASURING UNITS

For any depth work, with reel capacities from 5,000 feet to 15,000 feet of .072 line. Seven models are available for mounting in trailers, cars, pulling-units, and core drills. Self-powered by gasoline engine or power take-off models.

Write for Descriptive Literature

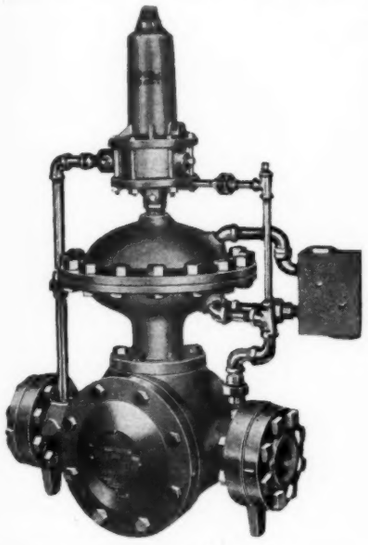
Gas Testing Equipment — Measuring Meters
Reeling Equipment for Well Shooting
Oxy-Acet Pipe Beveling Machines
Designers, Manufacturers of Special Machinery
WRITE FOR DETAILS

C. A. MATHEY MACHINE WORKS

Phone 3-3623 212 South Frankfort Tulsa, Oklahoma

are unattainable in former conventional regulator designs.

This manufacturer asserts it is no longer necessary to tolerate pressure fluctuations that in the past have been

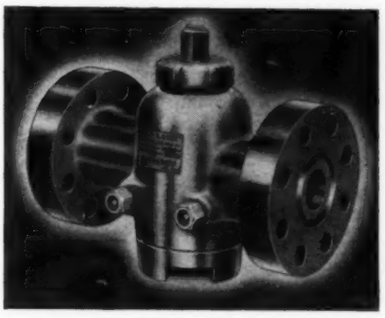


accepted as unavoidable in all regulators. With the new Emco controls, it is stated that regulation accuracies within 1 percent are commercially available.

The Emco Pilot Loading Control System is said to obtain a high degree of control accuracy for outlet pressures of 2 to 300 lb. and may be applied to any Emco high-pressure balanced valve regulator originally built for lever and weight loading as well as to the new regulators. For outlet pressures greater than 300 lb., the standard lever and weight loading is generally satisfactory because two-stage reduction should be employed for these higher pressures, and the second stage regulator can be arranged with pilot loading for close control of the final pressure. Bulletin 1055 will be sent to those who write to Pittsburgh Equitable Meter Company, 400 North Lexington Street, Pittsburgh, Pennsylvania.

Mission's Easy Operating Plug Valve

THE NEW plug valve manufactured by the Mission Manufacturing Company, Houston, Texas, has a cylindrical plug that is used to eliminate possibility of wedging. It also gives a close fit and makes a perfect seat possible. This reduces the possibility of abrasives working between the bearing surfaces, especially as there is also a patented automatic lubricating method that utilizes the line pressure to maintain a constant lubricating seal. This is a very interesting development, according to the manufacturer, as it eliminates a major plug valve problem —that of replacing the sealing lubri-



cant that gradually "washes" away. The Mission valve does this automatically and it is only necessary to be sure that a supply of lubricating grease is maintained in the small reservoir in the core, it is pointed out.

Due to the difficulty in obtaining machine tools, there has been some delay in placing the new valve on the market. Actually, at present, the valves are only available in 2-in., 3-in., and 4-in. sizes in both flange and screw types. Additional sizes will be manufactured as soon as it is possible to increase production sufficiently to supply the present requirements. All Mission valves are manufactured in three grades to meet 2000-, 3000-, and 5000-lb. working pressures.

THE MEDDLERS CAN'T GET AT IT . . .

but the mechanics can!

Factory filled and sealed, the Martin-Decker Unitized Mud Pump Gauge seldom requires attention of any kind. But if it should, you don't have to be a professional safecracker to get at it. For operators far removed from service or repairs this is important.

ALWAYS ACCURATE AND SENSITIVE ★ The oil-sealed Indicating Gauge on the Unitized withstands heat or cold without losing accuracy or sensitivity, and the Diaphragm and Pulsation Damper are built right into the rugged brass case. The Pulsation Damper, instantly adjusted for gauge hand overthrow, smoothes out reading under surging pressures, while the Diaphragm handles pressure up to 5000 pounds and completely seals the mud from the gauge mechanism. Vernier retard movement of the hand combines extreme sensitivity with high capacity for all operations. M-D flexo-glass lens and water-proof construction further assure trouble-free performance under all conditions.

So, if you're looking for a rugged, dependable instrument that will give years of service at low cost with minimum down time for repairs, you'll find it in the Martin-Decker Unitized Mud Pump Gauge. Why not investigate *today*? See your Martin-Decker Representative, or write direct!

HOME OF THE WEIGHT INDICATOR

MARTIN DECKER CORP.

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SAN JOAQUIN VALLEY: A. F. McQUISTON, BAKERSFIELD, CALIFORNIA
MID-CONTINENT DISTRIBUTOR: REED ROLLER BIT COMPANY, HOUSTON, TEXAS

Globe Rock Bit

ANNOUNCEMENT has been received by Globe Oil Tools Company, Los Angeles, California, of a new rock bit designated as the Series "J", developed especially for faster straight-hole drilling speeds in all formations.

The Series "J" is manufactured in six general types, each type having variations adapted to every formation from surface hole to bottom, such as quartzite, sticky shales, hard limes, dolomite, medium sand rock, granite, chalk, hard sand, etc. The Type "J-SD", for example, is for drilling in sticky shales as the widely spaced Hydrokleen teeth prevent balling-up in such formations; whereas the Type "J-XXX" is designed for fast hole in the hardest strata. Between these two extremes there is a special type adapted to every formation and condition.

The two-way inner cutters; five leg cutter support; Hevi-load bearings, and Hydrokleen teeth, are exclusive features, the manufacturer asserts. The first mentioned gives a double-action cutting surface that cuts through the hardest formations with maximum straight-hole penetration, positively eliminates tracking, and keeps the cutters clean under all conditions of service, the maker states. The patented fifth leg is an integral part of the bit body and provides strength far in excess of actual requirements for the support of gauge and inner cutters. In other words, instead of the gauge and

Globe Type "JGD-1" Rock Bit

inner cutters being supported from the outside legs only, each is anchored firmly on both sides by integral parts of the bit body. This added support also enables the cutters to maintain their proper alignment under the heaviest drilling loads, and assures maximum full-gauge hole on every run, it is stated. The cutters rotate on extra-large roller bearings, with ball thrust bearings that are said to assure more than sufficient strength to carry the heaviest loads.

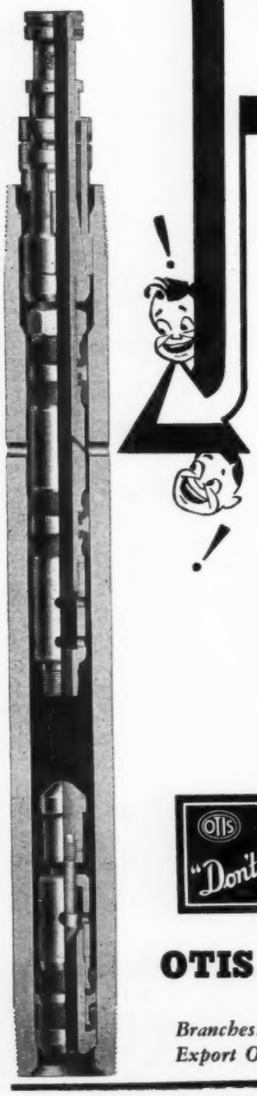
Oil-Field Light Plants

A NEW LINE of specially designed oil-field generating sets has been announced by the Novo Engine Company, Lansing, Michigan. These sets are easily portable, having sturdy steel skids with end loops. They can also be supplied mounted on trucks. Power

units can be equipped with combination gas and gasoline carburetor. The unit is completely weather-proof with a cover over the new super-safe switchboard, it is asserted.

These Novo generators are built in 15 different sizes and are powered by air- or water-cooled gas and gasoline engines or by Diesel units.

THE OTIS SIDE-DOOR CHOKE IS THE MAIN ENTRANCE TO A NEW ERA IN FLUID LIFTING METHODS



The Type G (Side Door) Otis Removable Bottom Hole Choke is the newest and most economical way to "kick-off" and flow your well when there is not enough pressure in the oil sand. Gas from an upper formation or from a surface source may be utilized with equal ease. Does away with pumping and expensive gas lift methods. The Otis Side Door Choke may also be used to clean out and test two separate horizons in the same well, and to produce from each formation independently of the other.

The Otis Side Door Choke is simple, removable, and will flow your well at controlled ratios. This is done by controlling the admission of gas into the tubing string from the annular space between the casing and tubing when: (1) A packer is set at the open hole to separate the oil and gas horizons; (2) A packer is set in the casing below perforations into the upper gas sand; or (3) Used above the normal fluid level of a well in which no packer is installed.

Control of the admission of gas is obtained through the side orifices drilled in the replaceable cup mandrel. A screw type or ground seat bean at the lower end of the cup mandrel may be used for additional control. The Choke is set in a special landing nipple by use of the successful Otis-type locking mechanism.

OTIS "Don't Kill Your Well" Call OTIS.

WRITE OR CALL TODAY. *Look in the yellow pages of your telephone directory under* "Oil Field Service" *for nearest Otis representative.*

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